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CARNEGIE INSTITUTION  
OF WASHINGTON

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Year Book  
No. 35

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1936



# CARNEGIE INSTITUTION OF WASHINGTON

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YEAR BOOK No. 35

JULY 1, 1935 — JUNE 30, 1936

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WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 11, 1936



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# CONTENTS

	PAGE
Organization, Plan and Scope.....	xi
Articles of Incorporation.....	xii-xiv
By-Laws of the Institution.....	xv-xviii
Minutes of the Thirty-Seventh Meeting of the Board of Trustees.....	xix-xx
Report of the Executive Committee.....	xxi-xxiii
Aggregate Receipts and Disbursements.....	xxiii
Report of Auditors and Financial Statement.....	xxv-xxxiii
Report of the President of the Institution.....	1-72

## Report on Investigations and Projects:

Division of Animal Biology.....	3-96
Department of Embryology.....	3-36
Department of Genetics.....	37-69
Nutrition Laboratory.....	70-80
Tortugas Laboratory.....	81-96
Geophysical Laboratory.....	97-110
Division of Historical Research.....	111-156
Mount Wilson Observatory.....	157-194
Division of Plant Biology.....	195-230
Department of Terrestrial Magnetism.....	231-280

## Other Investigations:

### Archæology

Caso, Alfonso.....	281-282
--------------------	---------

### Biology:

Castle, W. E.....	283-285
Conger, Paul.....	285-287
Dice, Lee R.....	287-289
Morgan, T. H., C. B. Bridges and Jack Schultz.....	289-297

### Chemistry:

Leighton, P. A.....	298-299
Urey, Harold C.....	299-301
Rabi, I. I.....	301

### Genetics:

Babcock, E. B.....	302-304
Davenport, Charles B.....	304

### Meteorology:

Bjerknes, V.....	305-307
------------------	---------

### Nutrition:

Vickery, H. B.....	308-312
Sherman, H. C.....	314-315

# CONTENTS

PAGE

## Other Investigations—continued:

### Palæontology and Geology:

Merriam, John C., and Associates .....	316-326
Stock, Chester .....	319-321
Kellogg, Remington .....	321
Buwalda, J. P. ....	321-322
Antevs, Ernst .....	322-323
Howard, E. B. ....	323
Richards, Horace G. ....	323-325
MacClintock, Paul .....	325-326
de Terra, H. ....	327-329
Campbell, Ian, and John H. Maxson .....	329-331
Hinds, Norman E. A. ....	331-333
Wieland, G. R. ....	333-340

### Physics:

Committee on Coordination of Cosmic-Ray Investigations .....	341-352
Compton, A. H. ....	343-346
Johnson, Thomas H. ....	346-349
Millikan, Robert A. ....	349-352
Committee on Study of Surface Features of Moon .....	353-355

### Physiography:

Sykes, Godfrey .....	356-358
----------------------	---------

### Physiology:

Russell, G. Oscar .....	359-363
-------------------------	---------

Point Lobos Studies .....	364-366
---------------------------	---------

### Psychology:

Ruger, Henry A. ....	367
----------------------	-----

### Seismology:

Advisory Committee .....	368-379
--------------------------	---------

Office of Publications .....	380-411
------------------------------	---------

Index .....	412-424
-------------	---------

## PRESIDENT AND TRUSTEES

**PRESIDENT**

JOHN C. MERRIAM

## BOARD OF TRUSTEES

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ALFRED L. LOOMIS                      WALTER S. GIFFORD

**Auditing Committee:** FREDERIC A. DELANO, *Chairman*

HOMER L. FERGUSON      WILLIAM BENSON STOREY



# FORMER PRESIDENTS AND TRUSTEES

## PRESIDENTS

DANIEL COIT GILMAN, 1902-04

ROBERT SIMPSON WOODWARD, 1904-20

## TRUSTEES

ALEXANDER AGASSIZ	1904-05	SETH LOW	1902-16
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FREDERICK H. GILLETT	1924-35	JOHN C. SPOONER	1902-07
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JOHN HAY	1902-05	WILLIAM S. THAYER	1929-32
MYRON T. HERRICK	1915-29	CHARLES D. WALCOTT	1902-27
ABRAM S. HEWITT	1902-03	HENRY P. WALCOTT	1910-24
HENRY L. HIGGINSON	1902-19	WILLIAM H. WELCH	1906-34
ETHAN A. HITCHCOCK	1902-09	ANDREW D. WHITE	1902-16
HENRY HITCHCOCK	1902-02	EDWARD D. WHITE	1902-03
WILLIAM WIRT HOWE	1903-09	HENRY WHITE	1913-27
CHARLES L. HUTCHINSON	1902-04	GEORGE W. WICKERSHAM	1909-36
SAMUEL P. LANGLEY	1904-06	ROBERT S. WOODWARD	1905-24
WILLIAM LINDSAY	1902-09	CARROLL D. WRIGHT	1902-08
HENRY CABOT LODGE	1914-24		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

# STAFF OF INVESTIGATORS FOR THE YEAR 1936

## Physical Sciences

### *Geophysical Laboratory*

Organized 1906, opened 1907.

\*ARTHUR L. DAY, Director

L. H. ADAMS

N. L. BOWEN

JOHN S. BURLEW

C. N. FENNER

MICHAEL FLEISCHER

R. E. GIBSON

R. W. GORANSON

J. W. GREIG

J. H. HIBBEN

F. C. KRACEK

C. J. KSANDA

H. E. MERWIN

G. W. MOREY

CHARLES S. PIGGOT

EUGENE POSNJAK

H. S. ROBERTS

J. F. SCHAIER

E. S. SHEPHERD

GEORGE TUNELL

FRED E. WRIGHT

E. G. ZIES

### *Seismological Research*

Advisory Committee in Seismology, Arthur L. Day, Chairman.

H. O. WOOD, Research Associate

HUGO BENIOFF

WILLIAM W. MILLER

CHARLES F. RICHTER

R. E. ROGERS

### *Mount Wilson Observatory*

Organized 1904; George E. Hale, Director 1904-1923.

\*\*GEORGE E. HALE, Honorary Director

WALTER S. ADAMS, Director

F. H. SEAKES, Assistant Director

ALFRED H. JOY, Secretary

A. S. KING, Supt. Physical Laboratory

J. A. ANDERSON

WALTER BAADE

HAROLD D. BABCOCK

THEODORE DUNHAM JR.

FERDINAND ELLERMAN

EDWIN P. HUBBLE

MILTON L. HUMASON

PAUL W. MERRILL

SETH B. NICHOLSON

FRANCIS G. PEASE

EDISON PETTIT

R. S. RICHARDSON

R. F. SANFORD

SINCLAIR SMITH

GUSTAF STROMBERG

A. VAN MAANEN

OLIN C. WILSON

### *Department of Terrestrial Magnetism*

Organized 1904; L. A. Bauer, Director 1904-1929.

J. A. FLEMING, Director

O. H. GISH, Assistant Director

L. V. BERKNER

F. T. DAVIES

C. R. DUVAL

C. C. ENNIS

S. E. FORBUSH

JOHN W. GREEN

L. R. HAFSTAD

H. F. JOHNSTON

P. G. LEDIG

A. G. MCNISH

WILFRED C. PARKINSON

W. J. ROONEY

W. E. SCOTT

K. L. SHERMAN

OSCAR W. TORRESON

M. A. TUVE

G. R. WAIT

W. F. WALLIS

H. W. WELLS

\* Retired November 1, 1936.

\*\* Retired July 1, 1936.

## *Department of Meridian Astronomy*

Organized 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director  
HEROY JENKINS

HARRY RAYMOND  
RALPH E. WILSON

## **Division of Plant Biology: H. A. SPOEHR, Chairman**

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology, in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

JENS C. CLAUSEN  
FREDERIC E. CLEMENTS  
WALDO S. GLOCK  
WM. M. HIESEY  
DAVID D. KECK  
FRANCES L. LONG

T. D. MALLERY  
H. W. MILNER  
FORREST SHREVE  
JAMES H. C. SMITH  
H. H. STRAIN

## **Division of Animal Biology: GEORGE L. STREETER, Chairman**

An administrative grouping made effective in 1935, including activities of the following Departments.

### *Department of Embryology*

Organized 1914; Franklin P. Mall, Director, 1914-1917.

GEORGE L. STREETER, Director  
CARL G. HARTMAN  
CHESTER H. HEUSER

MARGARET R. LEWIS  
WARREN H. LEWIS  
CHARLES W. METZ

### *Department of Genetics*

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934.

A. F. BLAKESLEE, Director  
M. DEMEREC, Assistant Director  
H. H. LAUGHLIN, Assistant Director  
A. G. AVERY  
R. W. BATES  
A. DOROTHY BERGNER

E. C. MACDOWELL  
JAMES S. POTTER  
OSCAR RIDDLE  
SOPHIA SATINA  
MORRIS STEGGIERDA

### *Nutrition Laboratory*

Organized in 1907, opened in 1908.

FRANCIS G. BENEDICT, Director  
T. M. CARPENTER

V. COROPATCHINSKY  
ROBERT C. LEE

### *Tortugas Laboratory*

Established in 1904. Alfred G. Mayor, Director 1904-1922. Open for marine biological studies during summer months.

W. H. LONGLEY, Executive Officer

## Division of Historical Research: A. V. KIDDER, Chairman

Department of Historical Research was organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

### *Section of Aboriginal American History*

SYLVANUS G. MORLEY  
EARL H. MORRIS  
H. E. D. POLLOCK  
O. G. RICKETSON JR.  
H. B. ROBERTS  
KARL RUPPERT  
A. LEDYARD SMITH  
GUSTAV STROMSVIK  
J. ERIC THOMPSON

### *Section of United States History*

\*CHARLES O. PAULLIN  
RALPH L. ROYS  
FRANCE SCHOLES  
LEO F. STOCK

### *Section of the History of Science*

GEORGE SARTON  
ALEXANDER POGO  
MARY WELBORN

### *Associated Investigators*

W. A. HEIDEL  
ELIAS A. LOWE

## Research Associates

SOPHIE D. ABERLE, Anthropology  
SEBASTIAN ALBRECHT, Astronomy  
C. B. BRIDGES, Biology  
PAUL S. CONGER, Biology  
A. E. DOUGLASS, Climatology

WALDEMAR JOCHELSON, Archaeology  
F. A. PERRET, Geophysics  
ARTHUR J. ROY, Astronomy  
JACK SCHULTZ, Biology

## Research Associates Engaged in Post-retirement Studies

EDMUND C. BURNETT, History  
CHARLES B. DAVENPORT, Biology  
D. T. MACDOUGAL, Botany

W. J. PETERS, Terrestrial Magnetism  
GODFREY SYKES, Physiography

## Research Associates Connected with Other Institutions

ERNEST ANDERSON (University of Arizona), Plant Biology  
M. J. ANDRADE (University of Chicago), Linguistics  
ERNEST ANTEVS (University of Stockholm), Climatology  
E. B. BABCOCK (University of California), Genetics  
I. W. BAILEY (Bussey Institute), Plant Biology  
J. BARTELS (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism.  
V. BJERKNES (University of Oslo, Norway), Meteorology  
G. BREIT (University of Wisconsin), Physics  
J. P. BUWALDA (California Institute of Technology), Geology and Palaeontology  
W. F. CASTLE (Harvard University), Biology  
RALPH W. CHANEY (University of California), Palaeobotany  
S. CHAPMAN (Imperial College, London), Terrestrial Magnetism  
A. H. COMPTON (University of Chicago), Physics  
G. GAMOW (George Washington University), Terrestrial Magnetism  
H. DE TERRA (Yale University), Archaeology and Palaeontology  
L. R. DICE (University of Michigan), Biology  
M. R. HARRINGTON (Southwest Museum), Archaeology

\* Retired August 1, 1936.

NORMAN E. A. HINDS (University of California), Geology  
 EDGAR B. HOWARD (University of Pennsylvania), Archaeology and Palaeontology  
 J. H. JEANS (Royal Society of London), Astronomy  
 THOMAS H. JOHNSON (Bartol Research Foundation), Physics  
 REMINGTON KELLOGG (U. S. National Museum), Palaeontology  
 A. E. KENNELLY (Harvard University), Terrestrial Magnetism  
 P. A. LEIGHTON (Stanford University), Chemistry  
 W. H. LONGLEY (Goucher College), Biology  
 R. A. MILLIKAN (California Institute of Technology), Physics  
 S. A. MITCHELL (University of Virginia), Astronomy  
 T. H. MORGAN (California Institute of Technology), Biology  
 FRANK MORLEY (Johns Hopkins University), Mathematics  
 ROBERT REDFIELD (University of Chicago), Anthropology  
 I. I. RABI (Columbia University), Chemistry  
 E. G. RITZMAN (New Hampshire Agric. Exper. Station), Nutrition  
 HENRY A. RUGER (Columbia University), Psychology  
 G. OSCAR RUSSELL (Ohio State University), Physiology  
 HENRY N. RUSSELL (Princeton University), Astronomy  
 H. C. SHERMAN (Columbia University), Nutrition  
 JOEL STEBBINS (University of Wisconsin), Astronomy  
 CHESTER STOCK (California Institute of Technology), Palaeontology  
 H. U. SVERDRUP (Scripps Institution of Oceanography), Terrestrial Magnetism  
 HAROLD C. UREY (Columbia University), Chemistry  
 H. B. VICKERY (Connecticut Agric. Exper. Station), Physiological Chemistry  
 BAILEY WILLIS (Stanford University), Seismology

## OFFICES OF ADMINISTRATION

JOHN C. MERRIAM, President

### *Office of the President*

JOHN C. MERRIAM, President  
 WALTER M. GILBERT, Administrative Secretary  
 SAMUEL CALLAWAY, President's Secretary

### *Office of Publications*

FRANK F. BUNKER, Editor  
 IRVING M. GREY, Secretary

### *Office of the Bursar*

EDMUND A. VARELA, Bursar  
 EARLE B. BIESECKER, Assistant Bursar

## ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment and continuous effort. Many close relations exist among activities of the Institution, and a divisional type of organization, representing investigations in plant biology, in animal biology and in historical research, has been effected in order to make possible a larger degree of unity and closer cooperation. A committee representing the interests of the Institution in the physical sciences facilitates research in that field. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publication provides means for appropriate publication of results of research, both in the form of technical monographs and as news bulletins.

## ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.*

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees herein-after appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh,

## ARTICLES OF INCORPORATION

Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said



## ARTICLES OF INCORPORATION

trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

## BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

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### ARTICLE I.

#### THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

### ARTICLE II.

#### MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

### ARTICLE III.

#### OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

## BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

### ARTICLE IV.

#### EXECUTIVE ADMINISTRATION.

##### *The President.*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

### ARTICLE V.

#### COMMITTEES.

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio*

## BY-LAWS OF THE INSTITUTION

and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

## BY-LAWS OF THE INSTITUTION

### ARTICLE VI.

#### FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

### ARTICLE VII.

#### AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

## ABSTRACT OF MINUTES OF THE THIRTY-SEVENTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 11, 1936. It was called to order by the Vice-Chairman, Mr. Forbes.

Upon roll-call, the following Trustees responded: Thomas Barbour, James F. Bell, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Stewart Paton, William Benson Storey, Richard P. Strong, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed.

The minutes of the thirty-sixth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1937 were authorized:

Pension Fund .....	\$ 60,000
Administration .....	64,950
Publications (including Office of Publications) ....	97,520
Departments and Divisions of Research .....	1,068,017
Minor Grants .....	104,750
General Contingent Fund .....	100,000
Special Emergency Reserve Fund .....	125,000
	1,620,237

The resignation of Henry S. Pritchett as a member of the Board was accepted with regret.

Balloting for new Trustees to fill three vacancies, occasioned by death of Mr. Wickersham, by resignation of Mr. Pritchett, and by absences of Mr. Montague, resulted in election of Robert Woods Bliss, of Washington, D. C., Henry S. Morgan, of New York, N. Y., and Charles P. Taft, of Cincinnati, Ohio. With unanimous consent, Mr. Root was also re-elected a member of the Board.

Mr. Root was re-elected Chairman of the Board, Mr. Forbes was re-elected Vice-Chairman, and Mr. Delano was re-elected Secretary for the ensuing period of three years.

W. Cameron Forbes, Stewart Paton, and Lewis H. Weed were re-elected members of the Executive Committee for a period of three years. Walter S. Gifford, Alfred L. Loomis, and Frederic C. Walcott were re-elected members of the Finance Committee for a period of three years, and Frederic A. Delano, Homer L. Ferguson, and William Benson Storey were re-elected members of the Auditing Committee for a period of three years.

The meeting adjourned at 12.30 p. m.



# REPORT OF THE EXECUTIVE COMMITTEE

For the Year Ending October 31, 1936

*To the Trustees of the Carnegie Institution of Washington:*

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1936.

During this year the Executive Committee held six meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 13, 1935, the members of the Executive Committee met and organized for 1936, Mr. Forbes having been elected as Chairman of the Executive Committee by the Board of Trustees.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith. Continuing attention has been given both by the Executive Committee and the Finance Committee to the question of income under present economic conditions. Budget recommendations for next year are based upon opinion of these Committees with respect to financial policy concerning protection both of capital and of income against possible losses and to existing difficult conditions in investment of funds.

The Board of Trustees, at its meeting of December 13, 1935, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1936. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1936, is submitted as a part of the report of the Executive Committee.

There is also submitted a financial statement for the fiscal year ending October 31, 1936, showing funds available for expenditure and amounts allotted by the Executive Committee. A customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, is included.

Two vacancies exist in membership of the Board of Trustees, one occurring through application of Section 2, Article I, of the By-Laws, Andrew J. Montague having been absent from annual meetings of the Board in 1933,



1934 and 1935, and the other caused by death of George W. Wickersham on January 25, 1936. Nominations to fill vacancies have been requested, received and distributed in accordance with provision of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 11, 1936.

Tenures of office of the following officers of the Board of Trustees will expire at the annual meeting on December 11: Mr. Root, Chairman of the Board; Mr. Forbes, Vice-Chairman of the Board; and Mr. Delano, Secretary of the Board. Tenures of office of Messrs. Forbes, Paton, and Weed as members of the Executive Committee, of Messrs. Gifford, Loomis, and Walcott as members of the Finance Committee, and of Messrs. Delano, Ferguson, and Storey as members of the Auditing Committee also expire at the meeting of December 11.

W. CAMERON FORBES, *Chairman*  
 FREDERIC A. DELANO  
 WALTER S. GIFFORD  
 JOHN C. MERRIAM  
 STEWART PATON  
 ELIHU ROOT  
 FREDERIC C. WALCOTT  
 LEWIS H. WEED

November 18, 1936.

*Financial Statement for Fiscal Year Ending October 31, 1936*

	Balances unallotted Oct. 31, 1935	Trustees' appropri- ation Dec. 13, 1935	Rever- tments and transfers Nov. 1, 1935, to Oct. 31, 1936	Total available 1936	Executive Committee allotments 1936	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1936
Large Grants:							
Animal Biology:							
Administrative Expenses.....		\$1,700		\$1,700	\$1,700		
Embryology.....		74,949	\$1,200	76,149	76,149		
Genetics.....		132,485	11,650	144,135	144,135		
Nutrition Laboratory.....		42,920	500	43,420	43,420		
Tortugas Laboratory.....		14,000	600	14,600	14,600		
Geophysical Laboratory.....		161,506	1,600	163,106	163,106		
Historical Research.....		160,980	1,500	162,480	162,480		
Meridian Astrometry.....		16,920	5,080	22,000	22,000		
Mount Wilson Observatory.....		220,570	21,000	241,570	241,570		
Plant Biology.....		99,170	13,600	112,770	112,770		
Terrestrial Magnetism.....		186,980	29,930	216,910	216,910		
Minor Grants.....	\$295.16	109,500	35,308.71	145,103.87	139,942		\$5,161.87
Publications.....	52,411.40	97,520	15,196.50	165,127.90	130,991.01		34,136.96
Administration.....		67,900	4,942.25	72,842.25	72,842.25		
Pension Fund.....		60,000		60,000	60,000		
General Contingent Fund.....	53,941.24	50,000	29,219.75	133,160.99	36,869.83	\$74,702.25	21,588.91
Special Emergency Reserve Fund.....		75,000		75,000	75,000		
	106,647.86	1,572,000	171,327.21	1,849,975.07	1,714,385.09	74,702.25	60,887.73

*Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1906*

RECEIPTS		DISBURSEMENTS	
<i>Interest from— Securities and Bank Balances</i> .....	\$40,506,284.41	<i>Investment</i> .....	\$59,913,417.40
<i>Colburn Fund</i> .....	52,015.74	<i>Pension Fund</i> .....	794,736.97
<i>Sales of Publications</i> .....	328,020.79	<i>Insurance Fund</i> .....	108,001.32
<i>Reversions</i> .....	740,189.41	<i>General Contingent Fund</i> .....	129,012.25
<i>Pension Fund</i> .....	80,029.61	<i>Special Emergency Reserve Fund</i> .....	121,247.55
<i>Insurance Fund</i> .....	11,738.94	<i>Special Reserve Fund for Ad- ministration Bldg. Additions</i> .....	11,730.67
<i>Special Reserve Fund for Administration Building Additions (Rentals)</i> .....	13,391.96	<i>Grants Large</i> .....	\$27,850,883.26
<i>Redemption and Sale of Bonds</i> .....	49,287,669.60	<i>Minor</i> .....	4,813,479.01
<i>Carnegie Corporation of N. Y.</i> .....	7,435,881.24	<i>Publications</i> .....	2,362,212.15
<i>Miscellaneous</i> .....	6,684.96	<i>National Research Council</i> .....	150,000.00
		<i>Administration</i> .....	1,961,361.07
		<i>Cash in Banks</i> .....	98,216,081.65
			333,825.01
			98,549,906.66

(\*) Including Administration Building, \$309,915.69, and Collection Charges.



## REPORT OF AUDITORS

TO THE BOARD OF TRUSTEES,  
*Carnegie Institution of Washington,*  
*Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1936.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were either verified by inspection or by certificates received from depositaries and custodians. As in the past years, the detail accounts of the Departments of Research in the field have been audited by the Bursar of the Institution and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost or value at date acquired, this being the established custom of the Institution. Real estate and equipment are stated at original cost and books on hand for sale at their sale prices.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations above stated, the accompanying Balance Sheet, statement of Receipts and Disbursements and detailed Schedule of Securities properly present the financial position of the CARNEGIE INSTITUTION OF WASHINGTON at October 31, 1936, and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY,  
*Accountants and Auditors.*

*New York, N. Y., November 30, 1936.*



*Receipts and Disbursements for Year Ending October 31, 1936*

RECEIPTS		DISBURSEMENTS	
<i>Interest and Dividends from Securities</i> .....	\$1,615,427.33	<i>Investments</i> .....	\$4,799,719.29
<i>Sales of Publications</i> .....	\$16.40	Accrued interest.....	17,650.26
Index Medicus.....	71.10	<i>Pension Fund</i> .....	69,541.26
Year Book.....	5,639.86	<i>Insurance Fund</i> .....	6,207.72
Miscellaneous Books.....		<i>General Contingent Fund</i> .....	24,145.71
<i>Recrutmnts</i> .....	5,727.49	<i>Special Emergency Reserve Fund</i> .....	34.99
Large Grants.....		<i>Special Reserve Fund for Administration Building Additions</i> .....	9,901.88
Contributions.....	6,763.43	<i>Grants</i> .....	
National Research Council.....	3,100.00	Large.....	1,206,819.50
California Institute Tech.....	12,599.88	Minor.....	119,134.86
Internat. Cancer Research Foundation.....	2,187.50	<i>Publication</i> .....	63,241.39
Geological Society of America.....	2,800.00	General Publication.....	260.42
		Catalogues, Advertising, etc.....	7,634.01
		Shipping Expenses.....	27,679.87
	27,450.81	Office of Publications.....	
<i>Minor Grants</i> .....	1,296.47	<i>Administration</i> .....	
<i>Publication</i> .....	1,975.49	Trustees.....	2,457.50
<i>Administration</i> .....	949.48	Executive Committee.....	5,014.02
Unappropriated Fund.....	28.21	Salaries.....	46,366.60
General Contingent Fund.....	226.05	Surety, postage, tel. & tel.....	2,099.58
		Printing, paper.....	970.25
<i>Pension Fund</i> .....	31,926.51	Office expenses.....	10,053.38
	5,921.46	Equipment.....	205.45
<i>Insurance Fund</i> .....	92.31	Building, maintenance.....	4,727.92
		Lectures and Exhibits.....	2,285.11
<i>Special Reserve Fund for Administration Building Additions (Rentals)</i> .....	2,042.25		
<i>Redemption and Sale of Securities</i> .....	4,128,647.08	<i>Cash in Banks, Oct. 31, 1936</i> .....	6,426,150.97
<i>Carnegie Corporation of N. Y.</i> .....	87,200.00	Uninvested Principal.....	2,685.18
		Awaiting investment.....	19,310.48
	5,876,984.43	Reserved for current needs.....	
<i>Balance in Banks, Oct 31, 1935</i> .....	882,991.55	Income Account.....	21,995.66
			311,829.35
	6,759,975.98		333,825.01
			6,759,975.98

# Schedule of Securities

Aggregate— Par or Nominal Value	Description	Registered		Maturity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Railways</i>					
\$500,000	A. T. & S. Fe. 1st & ref. 4½s.			1962	M-S	\$498,750.00
43,000	conv. 4s.			1955	J-D	39,022.50
50,000	A. T. and S. Fe. gen. 4s.	*		1995	A-O	50,056.25
50,000	Balto. & Ohio R. R. ref. 4s.			1941	M-N	46,875.
100,000	" " " " 1st Mtg. 5s.	*		1948	J-A-O	105,500.
100,000	" " " " " gen. and ref. 5s.	*		1995	J-D	102,416.67
50,000	" " " " " "			1996	M-S	30,307.50
200,000	Boston & Maine 1st 5s.			1967	M-S	195,812.50
100,000	Canadian National Ry. Co. 5s.			1969	J-J	98,500.
100,000	" " " " 4½s.			1957	J-J	112,000.
160,000	Canadian Pac. Col. Trust 5s.			1954	J-D	159,710.07
50,000	Canada So. con. 5s.			1962	A-O	49,021.50
175,000	Ches. & Ohio Ry. gen. 4½s.			1992	M-S	174,062.50
100,000	" " " " Eq. Tr., Series 1929 4½s.			1939-40	M-N	96,825.50
50,000	Cent. Pac. Ry. 1st ref. 4s.	*		1949	F-A	48,250.
180,000	Chicago B. & Q. R. R. gen. 4s.	*		1958	M-S	169,501.25
200,000	" " " " Ill. Div. 4s.	*		1949	J-J	200,000.
35,000	Chicago M. St. P. & P. 5s.			1975	F-A	31,853.50
189,000	Chicago, Ind. & L. 1st & gen 5s.			1966	M-N	189,461.25
140,000	Chicago M. St. P. & P. conv. adj. 5s.			2000	A-O	127,414.50
234,000	Chicago M. & St. P. Ry. gen. 4½s (\$5,000 fully reg. \$29,000 reg. princ.)	*	*	1989	J-J	227,162.50
120,000	Chicago & N. W. Ry. gen. 3½s.	*		1987	FMA-N	100,300.
200,000	Chicago & N. W. Ry. gen. 4½s.	*		1987	M-N	210,000.
300,000	Chicago, R. I. & P. Ry. 4½s.			1952	M-S	280,964.50
50,000	Chicago Union Station Co. 1st Mtg. 3½s.			1963	J-J	52,125.
100,000	Chicago & W. Indiana R. R. Co., cons. 4s.			1952	J-J	97,122.50
50,000	Clev. C. C. & St. Louis Ry., 1st 4s.			1939	J-J	45,500.
100,000	" " " " " ref. and imp. 4½s.			1977	J-J	99,272.50
100,000	" " " " " gen. 4s.			1993	J-D	78,006.25
50,000	Clev. U. Term. 1st sink. 5½s.		*	1972	A-O	51,612.50
125,000	Elgin J. & E. Ry. Eq. 5s.	*		1938	J-J	125,000.
300,000	Erie R. R. gen. 4s.			1996	J-J	242,937.50
90,000	Erie R. R., Eq. Trust 4½s.			1942-43	J-D	86,467.90
69,000	Gt. Nor. 1st ref. 4½s.			1961	J-J	69,053.25
117,000	Gt. Nor. Ry. gen. 4½s.			1977	J-J	114,806.25
173,000	" " " " " 5s.			1973	J-J	180,587.50
300,000	Ill. Cent. R. R., Joint 5s.			1963	J-D	311,291.50
121,000	Ill. Cent. R. R. ref. 4s.	*		1955	M-N	108,677.50
120,000	Ill. Cent. Eq., Trust, 4½s.			1942-43	A-O	115,194.64
200,000	Kan. City Term. 1st 4s.			1960	J-J	179,728.76
200,000	Kan. City, F. S. & M. Ry. ref. 4s (Ctf. Dep.)			1936	A-O	187,250.
225,000	Lehigh and L. E. 4½s.	*		1957	M-S	220,547.29
100,000	Lehigh V. H. Term. Ry. 1st 5s.			1954	F-A	104,750.
50,000	Long Island ref. 4s.	*		1949	M-S	48,285.
250,000	Louisville & N. R. 1st & ref. 4½s.			2003	A-O	249,125.
100,000	Mo. Kan. & T. 1st 4s.		*	1990	J-D	82,603.13
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s.			1977	M-S	212,762.50
200,000	Mo. Pac. R. R., Eq. Trust 4½s.			1939-42	M-N	192,206.79
150,000	Mobile and O. R. R., ref. and imp. 4½s (Certificate of Deposit)			1977	M-S	145,750.
55,000	Morris & Essex R. R. Co., Construction Mtg. 4½s.			1955	M-N	52,937.50
175,000	N. Y. Cent. R. R. ref. & imp. 5s.			2013	A-O	186,906.25
50,000	New York, Penna. & Ohio R. R. 4½s.			1950	M-S	52,500.
50,000	N. Y. W. and Boston 1st 4½s.	*		1946	J-J	49,187.50
150,000	Nor. Pac. ref. and imp. 6s.	*	*	2047	J-J	150,450.
50,000	" " " " " gen. lien 3s.			2047	FMAN	33,101.25
51,000	Ore. Short Line con. 5s.			1946	J-J	49,373.25
310,000	Ore. Wash. R. & N. 1st ref. 4s.			1961	J-J	274,272.50
80,000	Penna. R. R. Co. gen. 4½s.	*		1965	J-D	80,900.
125,000	" " " " " con. 4½s.	*		1960	F-A	130,703.13
100,000	" " " " " gen. Mtg., 5s.			1968	J-D	113,375.
50,000	Pere Marquette Ry. Co., 1st Mtg. 5s.			1956	J-J	44,282.60
200,000	Pitta. C. C. & St. L. 5s.			1975	A-O	211,987.50
42,000	Pitta. Shawmut & Nor. 4s (Ctf. Dep.)			1952	J-J	4,200.
125,000	So. Pac. 1st ref. 4s (\$100,000 fully reg.)	*		1955	J-J	116,617.50
200,000	So. Pac. 4½s.			1989	M-N	180,000.
350,000	So. Rwy. Co. 1st con. 5s.			1994	J-J	362,531.25
45,000	St. Paul Union D. 1st & ref. 5s.			1972	J-J	48,150.
225,000	St. Louis-S. F., prior lien 4s (Ctf. Dep.)			1950	J-J	203,431.25
32,000	Term. R. R. Assn. of St. Louis 1st Mtg. 4½s.			1939	A-O	30,400.
230,000	Term. R. R. Assn. of St. Louis 4s.			1953	J-J	208,984.25
210,000	Texas & Pac. Ry., gen. and ref. 5s.			1977	A-O	213,882.50
100,000	Toledo & Ohio Central Ry. Co., ref. & imp. 3½s.			1960	J-D	99,000.
2,084,000	Union R. R. deb. 5s.	*		1946	J-D	2,084,000.
140,000	Union Pac. 1st lien and ref. 4s.	*		2008	M-S	128,722.50
99,000	Union Pac. R. R. 4s.			1968	J-D	87,900.63
200,000	Virginia Ry. Co. 1st lien & ref. 3½s.			1966	M-S	200,000.
40,000	Wabash R. R. Co., 1st 5s.			1939	M-N	37,750.
200,000	Wabash Ry., ref. and gen. 5s.			1976	F-A	203,250.
100,000	West Shore R. R. Co., 1st Mtg. 4s.	*		2361	J-J	78,140.
200,000	Western Md. R. R. 1st 4s.			1952	A-O	162,100.
13,047,000	Railway Sub-Total					12,637,757.21

*Schedule of Securities—Continued*

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility</i>					
\$100,000	Ala. Power Co. 1st ref. 4½s.			1967	J-D	\$87,265.00
212,000	Ala. Power Co. 1st & ref. 5s.			1988	M-S	202,322.50
220,000	Am. Tel. & Tel. Co. deb. 3½s.			1961	A-O	222,200.
125,000	" " " " sink. deb. 5½s.			1943	M-N	130,260.62
265,000	" " " " deb. 5s.			1965	F-A	265,865.53
300,000	Appalachian Electric Power Co. 1st ref. 5s			1956	M-N	296,125.
300,000	Ark. P. & L. Co. 5s.			1956	A-O	292,312.50
172,000	Bell Tel. Co. of Canada 1st 5s.			1955	M-S	177,267.50
100,000	" " " " " "			1957	J-D	101,125.
300,000	Birmingham E. Co., 1st ref. 4½s.			1988	M-S	283,056.25
75,000	Blackstone Valley Gas & E. 4s.			1985	M-N	76,875.
300,000	Carolina Power & L. Co. ref. 5s.			1956	A-O	302,298.75
110,000	Cedar R. Mfg. & P. Co. 1st sink. 5s.			1953	J-J	109,560.50
380,000	Columbia Gas & Elec. Corp., deb. 5s.			1961	J-J	379,762.50
300,000	Columbus Rwy., P. & L. 4s.			1965	M-N	304,500.
77,000	Comm. Edison, 1st Mfg. 5s.			1954	J-D	82,660.15
158,000	" " " " " "			1981	M-S	115,465.49
18,000	Consolidated Edison Co. of N. Y. deb. 3½s.			1946	A-O	18,180.
32,000	" " " " " "			1956	A-O	31,840.
100,000	Detroit Edison gen. & ref. 4s.			1965	A-O	103,500.
325,000	Ga. Power Co. 1st ref. 5s.			1967	M-S	320,112.50
300,000	Gatineau Power, 1st 5s.			1956	J-D	298,750.
200,000	Gulf States Util. Co. 1st mtg. & ref. 4s.			1966	A-O	206,000.
90,000	Hackensack Water Co., Gen. & Ref. 5½s.			1977	J-J	97,243.75
100,000	Houston Ltg. & Power Co. 1st lien & ref. 4½s.			1981	J-D	98,375.
100,000	Idaho P. Co. 5s.			1947	J-J	100,750.
200,000	Illinois P. & L., 1st & ref. 5s.			1956	J-D	196,750.
200,000	Indianapolis P. & L., 1st 5s.			1957	J-J	198,806.25
200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s.			1955	M-S	202,182.50
300,000	Inter. Tel. & Tel. deb. 4½s.			1952	J-J	288,250.
280,000	Int. Rap. Trans. ref. 5s.	*		1966	J-J	276,701.
100,000	Iowa Southern Utilities Co. 1st & ref. 5½s.			1950	M-N	100,474.66
88,000	Louisiana Power & Light Co., 1st 5s.			1957	J-D	90,420.
125,000	Louisville G. & Elec. 1st & ref. 5s.			1952	M-N	121,468.75
300,000	Memphis P. & L. 1st & ref. 4½s.			1978	A-O	279,250.
100,000	Metropolitan Edison Co. 1st 4½s.			1968	M-S	109,470.
300,000	Milwaukee E. R. & L. ref. & 1st 5s.			1961	J-D	302,337.50
100,000	Minn. P. & L. 1st & ref. 4½s.			1978	M-N	92,156.25
50,000	Monongahela West Penn. Pub. Serv. Co. 1st & gen. 4½s.			1960	A-O	52,000.
98,000	Montana Power Co., 1st & Ref. 5s.			1943	J-J	97,791.75
50,000	Newark Cons. Gas Co., Cons. Mtg., 5s.			1948	J-D	50,750.
52,000	N. Eng. Tel. & Tel. 5s.			1952	J-D	51,748.
100,000	New Orleans Pub. S. 5s.			1955	J-D	99,200.
42,000	N. Y. Gas, E. L. H. P. pur. mon. 4s.			1949	F-A	34,620.50
65,000	N. Y. & Westchester Ltg. 5s.			1954	J-J	67,052.50
300,000	New York P. & L., 1st 4½s.			1967	A-O	286,125.
150,000	Northern Ind. Pub. S., 1st ref. 5s.			1966	M-N	152,887.50
200,000	No. States Power Co., ref. 4½s.			1961	A-O	195,000.
100,000	No. States Power Co., ref. 5s.			1964	M-N	108,513.75
100,000	Ohio Edison Co. 1st & Cons. 4s.			1965	M-N	100,500.
175,000	Ohio Power Co., 1st and ref. 4½s.			1956	J-D	163,439.06
50,000	Ohio Public Serv. Co., 1st & Ref. 5½s.			1961	M-N	52,513.75
50,000	" " " " " " 6s.			1953	M-S	54,455.
200,000	Okla. G. & E. 1st 5s.			1950	M-S	200,000.
100,000	Pac. G. & E. Co., 1st & ref. 3½s.			1961	J-D	102,500.
100,000	" " " " " " 4s.			1964	J-D	104,000.
100,000	Pac. G. & E. Co. gen. & ref. 5s.			1942	J-J	98,592.77
200,000	Penn. Electric Co., 1st & Ref. 5s.			1962	A-O	203,882.50
300,000	Penn. Power & L. Co., 1st mtg. 4½s.			1961	A-O	289,562.50
105,000	Penn. W. & P. 1st ref. 4½s.			1968	M-S	102,597.06
293,000	Phila. E. Co. 1st & ref. 4½s.			1967	M-N	294,450.79
50,000	" " " " Mtg. sink. 5s.			1966	A-O	56,500.
136,000	Pub. Serv. Co. of Indiana, 1st & ref. 6s.			1952	F-A	112,540.
70,000	Pub. Serv. of No. Ill. 1st Lien & Ref. 4½s.			1981	A-O	66,655.
160,000	Pub. Serv. of No. Ill. 1st ref. 5s.			1956	A-O	157,550.
60,000	Puget Sound Power & L. 1st & ref. 4½s.			1950	J-D	56,550.
50,000	" " " " " " 5½s.			1949	J-D	31,900.
75,000	Rochester Gas & Elec. Corp. gen. 5s.			1962	M-S	69,475.
10,633,000	Forward.....					10,475,592.88



## Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility</i>					
\$10,633,000	Brought Forward . . . . .					\$10,475,592.88
300,000	Shawinigan W. & P. 1st & coll. 4½s.			1967	A-O	286,212.50
50,000	So. Bell Tel. & Tel. 1st sink. 5s.			1941	J-J	47,687.50
200,000	So. Calif. Edison Co. ref. 3½s.			1960	J-J	197,000.
36,000	Syracuse Lighting Co. 1st and ref. 5½s.			1954	F-A	37,807.10
125,000	Tenn. E. & P. 1st and ref. 5s.			1956	J-D	127,037.50
300,000	Texas Electric Service, 5s.			1960	J-J	292,700.
200,000	Texas Power & Light Co. 1st & ref. 5s.			1956	M-N	205,143.75
120,000	Toledo Edison 1st. Mtg. 5s.			1962	M-N	115,800.
255,000	Union Elec. Light & Power Co. 5s.			1967	F-A	259,024.05
220,000	Utah L. & T. Co., ref. 5s.			1944	A-O	215,193.
300,000	Virginia Elec. & Power Co. 1st & ref. 4s.			1955	M-N	303,750.
235,000	Washington Water Power Co., 1st and gen. mtg. 5s.			1960	J-J	237,496.87
100,000	Western United Gas & Electric Co., 1st Mtg. 5½s.			1955	J-D	105,187.50
13,074,000	Public Utility Sub-Total . . . . .					12,905,632.65

Mortgages					
\$25,000	Empire Title and Guarantee Co., Guaranteed 1st Mortgage. Ctl. No. 1876 5%.	*	1939	FMAN	25,000.
100,000	Lawyers Mtg. Co. Guaranteed 1st Mtg. Ctl. No. 18397 5½%	*	1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5½% Mortgage	*	1935	A-O	80,000.
100,000	Guaranteed 1st Mortgage 1184 Cromwell Ave., N. Y. 5½%	*	1932	M-S	99,500.
100,000	Guaranteed 1st Mtg. N. W. cor. Westbury Ct. & Flatbush Ave., Brooklyn 5½%.	*	1933	M-N	100,000.
85,000	Mortbon Corp. of N. Y. Coll. Trust 2½%	*	1941-56	J-I	81,000.
90,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctl. No. 5½%	*	1938	A-O	90,000.
100,000	N. Y. Title & Mtg. Co. 1st 4½%	*	1940	J-I	100,000.
100,000	Title Guarantee and Trust Co. 1st Mtg. Ctl. 130037 3% Participating	*	1939	J-I	100,000.
780,000	Mortgages Sub-Total.				775,500.

Industrial				
25,000	Addressograph-Multigraph Corp. Deb.	5 1/2%	1945	A-O 25,000.
15,000	Allis-Chalmers Mfg. Co., Conv. Deb.	4s.	1945	M-N 18,258.
113,000	Aluminum Co. of A. 1st sink. deb.	5s.	1952	M-S 113,606.59
100,000	American I. G. Chemical Corp., conv.	5 1/2%	1949	M-N 105,861.25
50,000	American Radiator Co., deb.	4 1/2%	1947	M-N 49,125.
50,000	American Rolling Mill Co., Conv. Deb.	4 1/2%		
100,000	Bethlehem Steel Corp. Cons. sink fund	4 1/2%	1945	M-N 53,342.84
110,000	Lacka. Steel conv. 1st ss.		1960	J-J 98,500.
21,000	Pure Oil Co. sink. fund	4 1/2%	1960	M-S 112,925.
200,000	Rwy. Express Agency, 5s.		1950	J-J 24,780.
100,000	Remington Rand Inc., deb.	4 1/2%	1939-48	M-S 200,000.
25,000	Republic Steel Corp. Gen. Mtg. Conv.	4 1/2%	1956	M-S 100,162.50
100,000	Scovill Manufacturing Co., Conv. deb.	5 1/2%	1960	M-S 20,725.
250,000	Shell Union Oil Corp., Deb.	3 1/2%	1945	J-J 100,010
100,000	Socoxy Vacuum Oil Co., Deb.	3 1/2%	1951	M-S 247,500.
1,975,000	Tenn. C. I. & R. Co. 5s.		1950	A-O 100,000.
100,000	Texas Corp., deb.	3 1/2%	1951	J-J 1,975,000.
85,000	Wheeling Steel Corp. 1st Mtg.	4 1/2%	1951	J-J 100,000.
100,000	Youngstown S. & Tube Corp. deb.	3 1/2%	1960	F-A 86,275.
100,000	1st Mtg. sink. 4s.		1951	F-A 105,850.
			1961	M-N 98,500.
3,719,000	Industrial Sub-Total			3,744,421.18

<sup>1</sup>In the exchange of \$100,000 Mortgage Bond Co. of New York 5s, 1938, the Institution received 400 shares of Morthon Corporation of New York Voting Trust Certificate for Class A Capital Stock, which have not been included at any value.

*Schedule of Securities—Continued*

Aggregate Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Foreign</i>					
\$120,500	German External Loan of 1924 7s. ....			1949	A-O	\$128,738.53
100,000	Govt. of Argentine 6s. ....			1960	M-S	97,625.
115,000	Imp. Japanese Govt. 5½s. ....			1965	M-N	103,212.50
300,000	Kingdom of Denmark, ext. 4½s. ....			1962	A-O	274,375.
25,000	City of Montreal 5s. ....			1956	M-N	24,062.50
75,000	City of Montreal sink. 5s. ....			1964	M-N	72,375.
100,000	City of Montreal 4½s. ....			1946	F-A	94,368.90
198,000	New South Wales, ext. 5s. ....			1958	A-O	187,666.87
100,000	Province of Alberta deb. 4½s. ....			1958	J-J	93,750.
100,000	Province of Alberta 5s. ....			1950	A-O	101,150.
200,000	Province of Manitoba deb. 4½s. ....			1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s. ....			1952	M-S	100,312.50
100,000	Province of Ontario 4s. ....			1964	M-N	87,150.10
60,000	Province of Ontario 5½s. ....			1937	J-J	61,293.09
100,000	Province of Ontario 5s. ....			1959	M-N	99,789.63
40,000	Province of Ontario 6s. ....			1943	M-S	43,137.50
30,000	Prov. of Saskatchewan deb. 5s. ....			1943	J-D	30,627.44
84,000	Toronto Harbour Comm. 4½s. ....			1953	M-S	81,676.87
100,000	City of Toronto con. deb. 5s. ....			1949	J-D	96,164.59
90,000	City of Toronto, 5s. ....			1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s. ....			1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s. ....			1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s. ....			1946	J-D	95,375.
2,337,500	Foreign Sub-Total. ....					2,254,450.05
	<i>State and Municipal</i>					
50,000	City of Cleveland, Water Works, 5½s. ....			1967	M-N	52,984.60
25,000	City of Detroit, Water Supply, 4s. ....			1955	J-D	24,812.50
25,000	City of Detroit, Water Supply, 4½s. ....			1952	M-S	25,250.
50,000	City of Newark, Street Opening, 5½s. ....			1958	F-A	51,724.94
50,000	City of New York, 4½s. ....			1981	M-S	50,125.
50,000	City of New York, 4½s. ....			1979	J-D	51,750.
84,000	State of North Carolina, Highway, 4½s. ....					
50,000	(\$30,000 registered) .....	*		1953-63	J-J	92,819.50
	City and County of San Francisco, Hetch Hetchy, 5½s. ....			1960	J-D	53,523.34
384,000	State and Municipal Sub-Total. ....					402,989.88
33,341,500	BONDS—Funds Invested. ....					32,720,750.97
Number of shares	<i>Preferred Stocks</i>				Divids. Due	
500	A. T. & S. Fe pref. stock. ....				F-A	52,125.
2,000	Cons. Edison Co. cum. pref. stock. ....				FMAN	198,725.
1,000	Du Pont de Nemours, deb. Stock. ....				JAJO	116,125.
500	J. I. Case Thresh. M. Co. pref. stock. ....				JAJO	62,225.
400	Union Pac. R. R., pref. stock. ....				A-O	33,415.
5,000	U. S. Steel Corp., pref. stock. ....				MJSD	715,173.50
9,400	Preferred Stocks—Sub-Total. ....					1,177,788.50

*Schedule of Securities—Continued*

Number of Shares	Description	Total Cost or Value at Date Acquired
<i>Common Stocks</i>		
700	Air Reduction Company . . . . .	\$47,322.50
285	Ais-Chalmers Manufacturing Co. . . . .	12,147.
300	American Brake Shoe and Foundry Co. . . . .	14,395.
1,000	American Radiator & Standard Sanitary Corp. . . . .	21,912.50
700	Bethlehem Steel Corp. . . . .	43,297.50
600	Borg Warner Corp. . . . .	46,402.50
900	Caterpillar Tractor Co. . . . .	89,095.
500	Chrysler Corporation . . . . .	54,802.50
300	Continental Can Co. . . . .	23,685.
300	Continental Insurance Co. . . . .	11,979.
1,500	Continental Oil Corp. . . . .	49,737.50
200	Eastman Kodak Co. . . . .	34,450.
900	General Electric Co. . . . .	35,447.50
1,000	General Motors Corporation . . . . .	68,250.
200	Hartford Fire Insurance Co. . . . .	15,462.94
200	Humble Oil & Refining Co. . . . .	13,122.50
100	Ingersoll-Rand Company . . . . .	13,425.
400	Inland Steel Company . . . . .	41,499.
100	International Business Machines Corp. . . . .	18,275.
700	International Harvester Co. . . . .	60,227.50
800	International Nickel Co. . . . .	41,867.50
100	Johns-Manville Corp. . . . .	11,262.50
1,200	Kennecott Copper Corp. . . . .	51,920.
500	Monsanto Chemical Co. . . . .	46,862.50
1,000	National Lead Co. . . . .	28,075.
300	Owens-Illinois Glass Co. . . . .	44,975.
1,300	Phelps Dodge Corp. . . . .	48,932.50
400	Pittsburgh Plate Glass Co. . . . .	52,314.75
800	Sears Roebuck & Co. . . . .	64,027.50
400	Sherwin-Williams Co. . . . .	51,651.13
600	Standard Oil Co., of California . . . . .	23,102.50
1,000	Standard Oil Co., of N. J. . . . .	62,837.50
700	Texas Corporation . . . . .	26,105.
50	Travelers Insurance Co. . . . .	29,463.89
300	Underwood Elliott Fisher Co. . . . .	25,710.
700	Union Carbide & Carbon Co. . . . .	62,377.50
500	United States Gypsum Co. . . . .	48,915.
300	Westinghouse Air Brake Co. . . . .	12,587.75
500	Westinghouse Electric & Mfg. Co. . . . .	61,262.50
22,335	Common Stocks—Sub-Total . . . . .	1,489,167.46
31,735	Common and Preferred Stocks—Funds Invested . . . . .	2,666,955.96
	Aggregate Investments (Bonds and Stocks) . . . . .	35,387,706.93

*Real Estate and Equipment, Original Cost*

*Administration (October 31, 1936)*

*Washington, D. C.*

Building, site, and equipment.....	\$413,716.47
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*Division of Plant Biology (September 30, 1936)*

*Palo Alto, California (Headquarters)*

Buildings and ground.....	\$154,757.02
Laboratory.....	54,890.13
Library.....	27,847.40
Operating appliances.....	25,687.67
	263,182.22

*Department of Embryology (September 30, 1936)*

*Wolfe and Madison Sts., Baltimore, Md.*

Library.....	3,208.55
Laboratory.....	13,817.74
Administration.....	7,140.73
	24,167.02

*Department of Genetics (September 30, 1936)*

*Cold Spring Harbor, Long Island, N. Y.*

Buildings, grounds, field.....	292,264.69
Operating.....	30,670.52
Laboratory apparatus.....	26,004.79
Library.....	43,889.34
Archives.....	45,488.90
	438,318.24

*Geophysical Laboratory (September 30, 1936)*

*Upton St., Washington, D. C.*

Building, library, operating appliances.....	221,543.33
Laboratory apparatus.....	151,802.09
Shop equipment.....	18,196.37
	391,541.79

*Division of Historical Research (September 30, 1936)*

*Administration Building, Washington, D. C.*

Operating.....	17,318.94
Library.....	8,161.03
	25,479.97

*Tortugas Laboratory (September 30, 1936)*

*Tortugas, Florida*

Vessels.....	30,930.43
Buildings, docks, furniture, and library.....	12,930.86
Apparatus and instruments.....	9,322.55
	53,183.84

*Department of Meridian Astrometry (September 30, 1936)*

*Dudley Observatory, Albany, N. Y.*

Apparatus and instruments.....	4,846.84
Operating.....	5,273.68
	10,120.52

*Nutrition Laboratory (September 30, 1936)*

*Vila St., Boston, Massachusetts*

Building, office, shop and library.....	133,113.60
Laboratory apparatus.....	37,099.54
	170,213.14

*Mount Wilson Observatory (September 30, 1936)*

*Pasadena, California*

Buildings, grounds, road, and telephone line.....	217,195.37
Shop equipment.....	46,426.88
Instruments.....	667,653.48
Furniture and operating appliances.....	202,530.40
Hooker 100-inch reflector.....	608,328.47
	1,742,134.60

*Department of Terrestrial Magnetism (September 30, 1936)*

*5241 Broad Branch Road, Washington, D. C.*

Building, site, and office.....	228,047.90
Survey equipment.....	102,651.07
Instruments, laboratory and shop equipment.....	174,718.64
	505,417.61

4,037,475.42



REPORT OF THE PRESIDENT  
OF THE  
CARNEGIE INSTITUTION OF WASHINGTON  
FOR THE YEAR ENDING OCTOBER 31, 1936



# REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

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In accordance with established procedure, which is important for records of the Institution, the President has the honor to transmit to the Trustees of Carnegie Institution of Washington the following report on activities in the Institution for the year ending October 31, 1936.

Guided as this Institution is by objectives defined in its Articles of Incorporation as "investigation, research, and discovery, and the application of knowledge to the improvement of mankind"; it is necessary to make sure from time to time both that the investigations serving as basis for discovery really represent accurate, fundamental studies, and that the results find adequate application for improvement of mankind. Assuming that ultimate human use is the objective of all activities, it is not difficult for conscientious administration to stress application first, not remembering that importance, and even extent of use, may depend upon quality of the product, as well as upon both understanding and adaptability in application. On the other hand, it would be easy to slip into a groove in the movement of research and fail of relation to the agencies or activities in which the product of investigation is needed.

In examining our situation, a critical question inevitably raises itself concerning the real nature of the field which we occupy. Although in the Institution's activities



there has never been hesitation to extend the principle of investigation into any region where search for the truth and organization of verifiable knowledge can be conducted effectively, an evaluation of the contributions made will show that the "research" and its application in which we have engaged fall largely within the field of what is commonly recognized as "science," rather than in other aspects of investigation. This is in contrast to research extended more broadly over what we call human problems. Without suggesting change from existing policies, this may be an appropriate time to consider the relationships to research that have been established, and to examine some of their implications.

In past years the Institution has followed a policy in which flexibility was considered important. Science has been recognized as an attitude of mind representing search for the truth, and also as organized bodies of knowledge, such as the physical and biological sciences which have been built step by step to stages at which previously unrecognized generalizations or truths became visible. Research, or investigation, has been looked upon as the insistent development of effective means for securing information. The methods of science have been seen as one form of research. Investigation may be conducted in any field where the advance of knowledge or the search for truth is desirable. The methods of approach change according to subject or purpose in view. The investigator may attack problems of mathematics, physics, biology, psychology, economics, or government. Difficulties will vary greatly, as well as possibilities of attainment, but the effort to advance and organize knowledge is essential in each case.

Without attempting to define specific fields of thought in accordance with existing classifications, one may find justification for grouping the contributions of research under three subdivisions: first, the nature of man and his place in the world as we find it; second, the environment of man represented by the natural world; third, the constructive work of man as it tends to build new features or conditions relating especially to his own needs and desires.

A large part of science and research has been devoted to study of our physical and biological environment. In study of man himself we have made reasonable advance so far as morphology, physics, chemistry, and physiology are concerned. To a modest extent we have learned something concerning our psychological activities. There is still a vast range of questions through and around which to work on the general subject of the mind of man.

The study of man as a constructive or creative agent seems only to have begun. So far as this concerns understanding of man's opportunity in relation to the world about him, in relation to his environment of human beings, and in relation to his own interests and desires, we have barely entered the field.

The Institution has thus far limited itself largely to the securing of new data and to organization of information relating to mathematical research, investigation of natural phenomena as expressed either in the world about us or in man, and to history. Work in the natural sciences may have meant only that at given moments the evident fields for harvest in study of nature or of nature in man were large, and new methods opened opportunity for advance. However, there has been recognition also of a pos-

sibility that the next great steps forward might be through study of human problems, with methods as different from those used heretofore as are the present attacks upon natural science, by use of new instruments and new theories, compared with those of ancient times.

In examining the significance of work done by the Institution, and in considering policy for the future, it is important to keep in mind the fact that while our contributions have been largely in the field of science they have often concerned method at least as definitely as subject.

Although devoting itself almost exclusively to the task of searching for new information, organizing it, and making it of record, the Institution has been aware also of the fact that the value of science in terms of its contribution to meet human needs is shown in an almost infinite variety of ways. The relations of physics to engineering, or chemistry to medicine and industries, or biology to medicine, are things which may have immediate human use of easily recognizable and measurable type. Also the value of scientific methods as means for testing of data is seen as of the first order of importance in our struggle to make reality and truth the source of all activities designed to further human betterment.

One phase of the problem of modern science in its relation to civilization under discussion in recent years concerns the ways by which science can be utilized in an effective manner to meet great needs in difficult human relations such as those represented by economics and government. On the one hand there is the view that science is not qualified to deal with those human problems in which the peculiar qualities of mind are factors of primary importance. Another point of view is expressed in the idea

that science should extend its field by application of existing and yet to be discovered methods so as to conquer in the fields of economics, sociology, and government.

An intermediate view, which has been followed commonly as policy of the Institution, has involved recognition of the possible aid of science in study of important human questions, but with assumption that the best method of procedure is by a meeting of minds in which the sociologist, economist, or student of government brings into cooperation with him representatives of science whose methods or problems are most nearly allied to his own. It is certainly to be doubted whether, even if the methods of science are desirable, it is the scientist who should proceed unaided with this application in the fields of economics, sociology, and government.

What might be called practical application of our research results, ranging from the physical and biological sciences to human values, as in psychology, has been the subject of most careful consideration for some years by committees of the Institution. We have endeavored to make sure that the materials secured find their place through examination by experts in the field of application. These studies have been conducted with the hope of bringing to certain applying groups, as in medicine, new materials or points of view which might otherwise remain for a considerable time unused. At the same time the Institution has given careful attention to interpretation of scientific truths such as might aid in forming principles or guiding thought. A beginning has been made also in conference with students from the field of human research with relation to common problems.

Continuing advance of civilization is made possible as

absorption of discoveries and methods of work in each generation helps to form habits of thought in subsequent stages. The real dangers which arise from instinctive action on matters involving logic we assume to be balanced by the possibilities of accelerated action due to accumulated knowledge. The techniques and technologies which arise out of science to become a part of everyday life in industry, or in more distinctly personal activities, may in considerable measure be merely the standardized methods of science developed to a point where they are called arts. Without assuming unanimity of opinion on the subject, there is wide acceptance of the idea that the dangers arising from speeding up of techniques and technologies which lead to development of new activities and industries is at least balanced by development of greater adaptability to new conditions as they arise.

From a number of directions we have the suggestion that for guidance in development of new ideas, and for the protection of society, it is desirable to set up types of organization which may bring together scientists, engineers, and forward-looking students of social and economic problems with a view to keeping close watch upon related problems in these several fields. The finding of something like common viewpoints for investigators in different subjects may be difficult but it will have increasing importance. Such an activity might be established in the hope of fitting new ideas and new techniques to advancing industries and to new phases of social and economic endeavor. If developed guardedly, such a forward-looking program presumably would not hinder the advance of civilization, and might be expected to aid in

adjustment of human groups to some of the changes which inevitably take place.

It is important to note that responsibility for keeping in view the possibility of social influences arising from use of scientific techniques rests in part upon the scientist. Assuming that there will be an uneven movement in the economic-social stream, there is value in having those best acquainted with the nature and possibilities of new materials and new activities keep in mind the fact that they, as the source of such influences, should have some acquaintance with ultimate application of their products. At the same time it must be realized that unwise use may be due to factors of social significance with which the student of social problems should plan to keep close acquaintance.

In following the implications of these questions it is important to examine the idea that scientific methods may function as techniques which in various ways influence modes of thought and even concern aspects of judgment. If science exerts this influence, it is essential that its contribution be guarded with the greatest care as to use in education, and also watched by the ablest students as to the manner in which it may affect or guide thought. As one possible influence of science upon thought, we may assume that if the minds of all citizens could be so informed and trained that, as a rule, there would be insistence upon having and using the elements of fact and reality, which are the basis of science and research, there would be guaranteed a relatively safer situation with reference to the handling of all human problems than has commonly obtained.

Even in the broader relations of society which concern

affairs of nations and peoples, one may recognize the method of the scientist and the investigator as having a significant influence. As contrasted with economics and government, the relations of culture, and art in the broader sense, may have a larger element of mutual human interest. For this reason international culture is seen as one of the factors drawing together peoples which at any given moment may have widely differing economic and political ideas.

**International  
Influence of  
Science**

In a measure, comparable to what develops out of cultural contacts, science often represents vital interests of peoples of such a nature that results obtained have a high degree of mutual value. Science has both cultural and economic values, but in relations between peoples the cultural influence may be relatively important.

Added to other features of significance in the bearing of science upon international relations, it is important to note that for a great number of scientific problems the solutions can be obtained only by cooperation of nations, or perhaps by the peoples of the whole world. So in activities of this Institution, specifically in researches of the Department of Terrestrial Magnetism, many of the problems require cooperation of investigators over the entire world for securing of observational data, while the results find instant use in every part of the globe. In another direction, studies concerning oceanography and certain aspects of marine biology can be advanced only through international cooperation, and the results are of immediate use in many countries. The researches of Dr. V. Bjerknes, in Norway, conducted with the cooperation of the Carnegie Institution, in the field of fundamental physical-mathematical studies relating to the atmosphere,

have contributed to the advance of meteorology in every country of the world. Investigations by the Geophysical Laboratory on the nature of the earth, and with particular reference to volcanic phenomena, have needed the results of studies in the United States, Japan, East Indies, Africa, Europe, and South America. At all times there has been the utmost of cooperation from all countries which have been touched, and the results have become available for the peoples of these regions.

It is interesting to observe that among the nations of the world at the present time the contributions of science and culture have tended to bring together, and hold together, some of those units which have relatively small power in the sense of international control, but in which the cultural and scientific influences have certainly furnished guidance of exceptional significance for the world.

Assuming that the major contributions to science and research made by the Institution relate to man's environment, along with his physical structure and functioning, rather than to man in the strictly human sense, or to his creative work, it is important to note that investigation of our environment is largely of the analytical type. But there is another feature of the problem which requires attention, and for which the need is not less than for other kinds of investigation. This is the examination of our surroundings in the sense of their unity or their synthetic value.

**Science and the  
Unity of  
Our Environment**

The universe in which we find ourselves is the product of what seem to us practically infinite ages of creative activity, building the earth, shaping it to the present configuration, and peopling it with a vast range of life. In



this world the elements have been adjusted to each other through eons of give and take and evolution, until a tremendous complex faces us with its parts well fitted together. Man grew up in this environment, being in fact a part of it and a growth out of it. His whole being has been attuned to it physically, intellectually, and spiritually.

Man with his creative mind proceeded then to develop that type of organized effort which made beginnings of common culture possible and also, in the social sense, heritable. Groups of men extending their activities through society began here a battle with their surroundings. Suspicion of the shadowy forest and fear of the torrent gave place to contempt as man saw himself becoming master. And soon he was not merely conquerer but a destroyer. Forests fell in his march. Living creatures became vassal, or fugitive, or they vanished. In joy of use, man's creative work produced a new world, in which much of what remained was ordered to suit his needs or to please his fancy. The values of adjustment and interplay in nature, established through ages of growth and evolution, were no longer in balance, for, in part, man's will had been substituted for this balance. Much from the original elements of nature remained, but the unity and the synthetic factors were changed. The resources of nature upon which man is dependent continued in considerable part as separate elements, but the organization was disrupted, and many of the values were lost.

In recent decades mankind has raised question as to what it is that has been lost, but the answer can be given only in terms of original materials and of conditions now largely destroyed. Only in part has science mastered the

problem of the organized natural world as resulting from the creative process. To a still less extent did the agencies concerned in destructive processes learn to know what it was they destroyed.

We have come now to learn that a forest is not just board feet per acre, but consists of all the elements in life from the most insignificant to the greatest, and if it is to be replaced it must be on the basis of all values concerned; so it is with the whole natural world.

In discussing the functions of research and science as they concern man with reference to his being, his constructive activities, his relations with his surroundings natural and human, it is desirable to note that the physico-biological environment is not just atoms, rocks, chromosomes, plants, and animals. It is also the picture of these things composed by nature in the millions of years during which the perspective of space, and time, and color, and movement, and growth was being defined. Perhaps what we call beauty in it all is partly an expression of inheritance in a mind so long accustomed to these values that they seem inherent in thought.

Research on this phase of nature so far as it concerns individual natural resources calls attention to the possibility that many values not now appreciated, but to be needed later, are perhaps in process of extinction. Not until we have come to know all of our present and future needs and all that is in nature, with the relation between these elements, should we permit anything to disappear, or allow the types of adjustment attained in nature to be dislocated. Examination of any part of the world that has passed through the development of intensive civilization

shows the modifying influence of man upon the face of nature.

The progress in America through recent decades of what we call conservation, and for the world as a whole through centuries, has concerned itself with preservation and best use of our inheritance in nature. Conservation and replacement of forests still remains one of our most interesting and important problems, partly by reason of the fact that the forest is in general still an element of wild nature in the process of domestication and utilization. The vigorous discussion of conservation problems in other lands, and in our own country at the moment, expresses in various ways the values involved in this question. The fundamental elements are worthy of the most intensive study as to their scientific meaning, and ultimately in terms of their human significance.

To some extent the Institution has concerned itself with research on the environment as here considered. Studies of Dr. R. W. Chaney upon the history of environments, physical and biological, in the western part of America and in Asia make a contribution to biology and history of much importance. The work of Dr. F. E. Clements on the ecological problem in America has made many new paths which future investigators and applicers must follow. Activities of the Division of Plant Biology, concerned at the same time with study of hereditary factors in plants and with the relation of plants to their environment, furnish a safe foundation on which to build. And this program is advanced by cooperation with leading investigators throughout the world.

A problem of limited scope has been examined recently in the study of a small area on the coast of California

containing the only existing remnant of a primitive Monterey cypress forest with its associated plants and animals. The research has given opportunity for examination of a question of this type from the point of view of all sciences concerned, and with consideration also of human use extending out even to the securing of expert knowledge on scientific values as they touch the field of æsthetic appreciation. The cooperation of the Carnegie Corporation of New York in furtherance of this study at Point Lobos has made feasible the conduct of an investigation which will have lasting influence in the study of man's relation to his environment.

#### ASTRONOMICAL RESEARCH

Building upon the program of Mount Wilson Observatory developed since 1904, research in the field of astronomy has continued in the past year to produce a large number of contributions of importance. In the work of the Observatory a stage has been reached at which the great accumulation of data permits the forming of new patterns with new theories and new points of view. Once this level of productiveness is attained, the contributions may be both numerous and important.

In the field of investigation in the course of the past year, the report of Mount Wilson Observatory indicates that the most remarkable occurrence in astronomy was the appearance of a bright nova in the constellation of Lacerta on June 18. The visible outburst within the period of 18 months of two such stars, both visible to the naked eye, one being Nova Herculis, 1934, and one Nova Lacertæ in 1936, is recognized as of exceptional importance in the history

of astronomy. The report of Mount Wilson Observatory for the present Year Book notes that both stars have been studied extensively at observatories over the world and the final analysis of observations should contribute in an important way to interpretation of this extraordinary class of objects. Reference is made to the most recent nova, namely, the one in the constellation of Lacerta, as "of exceptional interest for several reasons: the rapidity with which the changes in light and spectrum have taken place; the magnitude of the velocities and accelerations of the expanding gases; the definite identification of the nova with a star of the fifteenth magnitude observed in past years; and the presence of strong lines due to calcium and sodium gas scattered throughout interstellar space." It is noted that velocities of approach amounting to as much as 3400 km per second have been observed in the expanding envelope of Nova Lacertæ, this being the highest velocity ever measured in novæ belonging to our galaxy. At its greatest brightness this star had a luminosity of about 150,000 times that of our sun.

Nova Herculis, which has attracted so much attention, remained relatively stable throughout the year, both as regards brightness and spectrum, but the star has been kept under close observation for radical changes which might be expected to occur in its nebular features. Careful study of the nova is reported upon by Mount Wilson Observatory to the effect that "most of the absorption lines and emission bands have been identified, and the remarkable changes in the widths and characters of the bands have been traced and recorded. The fact that forbidden states of the atoms of gas directly between the observer and the star can not give rise to absorption lines may well

explain the relative behavior of the permitted and forbidden lines in the spectrum; and the hypothesis that the expanding atmosphere of a nova arises from an explosive impulse which drives off highly condensed material from the star, out of which gaseous atoms later evaporate, would account for many of the complex changes observed."

Another important feature of the work of the Observatory concerns the discovery at Mount Wilson a few months ago of a super-nova in one of the extragalactic nebulae of the Virgo cluster, this adding an important member to the brief list of these remarkable stars. This discovery was made as the result of a long, systematic search and provides one of the most reliable determinations of the luminosity of the brightest objects of which we have knowledge. According to the report of the Observatory, "at maximum light it was at least one hundred times as luminous as Nova Lacertae and twenty million times as bright as our sun. Observations of its spectrum showed exceedingly wide emission bands, in agreement with the conclusion derived from galactic novae that the width of these bands is at least roughly proportional to the luminosity of such stars."

Rapidly developing knowledge concerning the types of galaxies, or island universes corresponding to the Milky Way system of which our solar system is a part, has extended the possibility of acquaintance with the wider universe about us, and has brought a vast amount of important information bearing upon our own star system. An extensive preliminary survey for the purpose of forming an estimate of the number and distribution of the extragalactic nebulae has been completed. This gives information of great importance regarding problems in that field

which may be investigated with large telescopes. The survey has led to many results of interest, among which are the determination of the relative numbers of nebulae of various luminosities, the evidence that the total luminosities of regular nebulae of all types are closely comparable, and the development and improvement of methods of deriving distances. Detailed studies of individual nebulae have led to important advances both on the spectroscopic and photometric sides. As is noted in the report, "evidence has been gathered which indicates that the unresolved, elliptical nebulae are probably clusters of stars with a range in spectral type not exceeding one or two spectral classes. A definite scale of magnitudes and colors for nebulae has been established through measures with the photoelectric photometer, and comparisons with observed spectral types show the existence of a color excess for all nebulae except the late-type spirals. A beginning has been made upon the difficult problem of measuring the rotation of extra-galactic nebulae spectroscopically, an investigation for which a special instrument is now under construction."

In the investigation of remote nebulae, intensive study has been given to measurements of the red shift, or the movement of lines in the spectrum toward the red end of the series. This problem is one of the most interesting in the whole field of astronomy and astrophysics. If the shift of spectral lines toward the red means increasing velocities of these objects in a movement away from the earth, there is raised a problem of an expanding universe in which the objects most remote would seem to be moving away from the earth with the highest speeds. Considerable

progress has been made in this study during the present year, with recognition of the fact that this is one of the great principles involved in the general study of cosmogony. A provisional analysis of the observed results by Dr. Hubble of Mount Wilson Observatory and Dr. Tolman of California Institute of Technology indicates that if the shift to the red is due to velocity, a positive curvature of space must be recognized with a radius within the observing range of the 100-inch telescope. An observation bearing on the problem of the red shifts has been made with a grating spectroscope on one of the brighter nebulae. The same shift is found as with a prismatic instrument, a result which disproves the suggestion that the frequency of the vibrating light-source may vary while the wave-length remains constant. The constancy of the velocity of light in its passage from the nebulae had already been established within narrow limits by measures of aberration on a cluster of distant nebulae.

The Observatory has concerned itself over many years with problems relating to the structure, form and dimensions of the galactic system or stellar system in which we reside. Evidence of unusual interest has recently been obtained on this problem from study of the globular star clusters which are among the most remote objects in this system, and therefore help to serve in determining the dimensions and shape of the galaxy. As noted in the report of the department, "measures of the color of these clusters with the photoelectric photometer by Stebbins and Whitford indicate that, when allowance is made for the effect of absorption by interstellar matter, the overall diameter of the galaxy is reduced by about one-half, or to 100,000 light-years, which is of the same order as that



of the Andromeda nebula. 'This result removes most of the discrepancy hitherto supposed to exist between the size of our galaxy and that of other systems.'

Recent work of the Observatory relating to distances of the fainter stars has shown that their distribution and the dimensions of our galaxy depend to a very large extent upon accurate measurements of stellar brightness and the evaluation of absorption due to cosmic dust and interstellar clouds. Important studies lead to the interesting conclusion that obscuring material is present in the polar regions in sufficient quantity to redden these stars by about one-tenth of one magnitude.

The possibility of sudden fluctuations in activity of the sun has made clear the importance of an unbroken record covering various types of solar phenomena. The Observatory has recently added to its regular program a continuous series of small-scale hydrogen spectroheliograms made automatically on a moving-picture film for the purpose of detecting bright hydrogen eruptions—outbursts of intensely luminous gas, usually closely localized, which occur in the immediate neighborhood of sun-spots. As is noted in the report of the Observatory, "these rather rare phenomena have lately become of special interest because of several well-authenticated coincidences of hydrogen eruptions with radio fading and disturbance of the earth's magnetic field, and also because there is now rather strong evidence that the eruptions occur simultaneously in two or more spots with a frequency too great to be attributed to chance. If future observations confirm the present indications, the conclusion will be that the bright hydrogen eruptions, notwithstanding their localized appearance, are

manifestations of some deep-seated phenomenon, and hence probably an important index of solar activity."

Among other studies of the sun, one of the most interesting conducted by the Observatory is indicated in the report relating to eruptive prominences on the sun which may arise with explosive violence. The report states: "As compared with terrestrial motions the velocities are always high, and on occasion the curved jets and streamers may reach an elevation of several hundred thousand kilometers in a few minutes time. The origin of the forces involved is still unknown, but some of the characteristics of the motions have now been learned. As stated in an earlier report, the velocities of the ordinary eruptive prominences remain constant, usually for intervals of about an hour, then suddenly increase. During the year a second characteristic of the motions has been announced: The new velocity following a sudden acceleration in a small multiple of the preceding velocity. Two or three separate accelerations during the life of a prominence are not uncommon, and in the 40 prominences thus far measured in detail there are no exceptions not easily explained by special circumstances. One class at least of the much rarer sun-spot prominences seems also to follow these laws of motion. The import of these results is yet to be learned, but there can be little doubt that they are of great significance."

In connection with the regular work of Mount Wilson Observatory an effort has been made to give opportunity for especially interested persons to experience for themselves the reality of astronomy by at least a brief look through the 60-inch telescope on the open evening once each week, and possibly to see the extraordinary type

of mechanism represented by the 100-inch telescope. In order to make the program involving this relation to the public more effective, the Trustees of the Institution have made available in the past year funds necessary for construction of an exhibit room and auditorium on Mount Wilson, where an especially assigned member of the staff will discuss in the most effective manner actual work of the Observatory, and where exhibits representing mainly the photographic work of the Observatory can be shown to advantage. Lectures will be given in this building on evenings when the public is admitted to the 60-inch telescope and the exhibits will be open for use each day. By these arrangements it is expected that in a modest way especially interested persons may have this means of knowing what the work of an observatory is and the type of materials upon which the studies are based.

In one of the most interesting cooperative investigations carried on at Mount Wilson, the Committee on Study of Surface Features of the Moon, under the guidance of Dr. F. E. Wright, has developed photographs of the moon, which have been satisfactorily transferred to glass globes, making possible presentation of the surface features in their natural relations. As noted in the report, this Committee has developed a new method "for ascertaining the shapes, slope angles, and relative heights and depths of lunar surface features. For the purpose an accurate polar perspective projection chart is projected on lunar photographs taken with the 100-inch telescope. With the aid of the chart, the angle which the sun's rays include with the normal to the moon's surface at any given point can be read off directly; also the angular

and linear dimensions of any feature, such as a crater. If, for example, the angle of elevation of the sun's rays is less than the slope angle of a crater wall, the wall casts a shadow; if it is greater, the slope is illuminated; if angle of elevation and slope angle are equal, grazing incidence is observed. The method is rapid and enables the observer to gather a surprisingly large amount of information on the shapes and dimensions of lunar surface features with fair accuracy and little or no computation."

As has been the case in recent years, the staff of Carnegie Institution, operating through its special committee for this important purpose, has cooperated so far as possible with California Institute in advancing research upon the program developed for the 200-inch telescope. Out of the many years' experience with the 100-inch telescope, as the largest instrument in operation, and through the aid of a number of members of the staff who have devoted themselves especially to this work, it is planned to give such aid as can be contributed in furtherance of the great 200-inch project.

The important and long-extended work of the Department of Meridian Astrometry, devoted specifically to determination of the positions of stars down to the seventh magnitude, was brought practically to completion in the past year, and a part of the publication of results is accomplished. The remaining portion will be brought to publication as rapidly as this is feasible. Certain of the more critical problems which grow out of this large work will, it is hoped, be examined through special investigations, either by members of the staff that was assembled in this Department or by other investigators.

## DEPARTMENT OF TERRESTRIAL MAGNETISM

Established for study of the scientifically difficult and, in practical application, humanly important questions concerning the earth's magnetic field, the Department of Terrestrial Magnetism has conducted one of the most difficult of our physical researches on the nature of the earth. The relationships and practical values of this investigation have looked, on the one hand, toward the fundamental characteristics of matter and, in another direction, toward utilization of data obtained from study of the field of earth magnetism to problems of navigation and related questions.

As is noted in the report of the Department, the problems of earth magnetism have so long baffled investigators that some deem it necessary to postulate for their solution an entity which may hold the key both to problems of terrestrial magnetism and terrestrial electricity, but which as yet is unknown to physics. Others continue to expect that as details of the phenomena become more fully known and are adequately integrated, a solution will be found requiring no new postulate. According to the first view, assuming the existence of further facts, investigations on the fundamental constituents of matter and their interactions would hold promise of indicating a solution of these riddles. According to the other view, attention should be directed rather toward obtaining more information about the phenomena under examination and concerning other gross geophysical features upon which these phenomena depend. In order to assure adequate consideration of the whole problem, the researches of the Department have been designed to test both of these views.

The work of the Department has necessarily been conducted both through observations in nature free from human influence and in the laboratory, where it has been possible to develop controlled conditions and new situations which may throw light upon the question of magnetism.

In further reference to the report of the Department the following quotation seems pertinent: "All known fluctuations of the Earth's field except those of long period—that is, the secular change—are demonstrably due to two causes; one acts above the Earth while the other acts within it. The more rapidly varying aspects of magnetic effects of internal origin seem attributable to induced electric currents circulating within the conducting substance of the Earth. Manifestations of these earth-currents have been registered at the Department's observatories for more than a decade. Through cooperation with other organizations, similar registrations have been obtained from several other widely separated places. Thus, during the past year, it became possible to construct a world-map of the electric currents circulating within the Earth and of their shift from place to place throughout the day.

"From magnetic observations alone, modes of circulation of electric current in the atmosphere and in the Earth may be inferred. Such current-systems, both inside and outside the Earth, which would give rise to the world-wide features of magnetic storms, were constructed by formal mathematical analysis. They revealed that the currents circulate about the geomagnetic axis of the Earth with maximal densities of flow in the tropics and in the auroral zones. The currents which would give rise to magnetic

'bays'—fluctuations in the Earth's magnetism of duration about an hour, more or less—have also been inferred. The principal aspect of these currents is a westward flow in the high atmosphere along the auroral zone on the dark side of the Earth with the associated return flow in the high atmosphere and the concomitant currents induced within the Earth. The hypothesis has been advanced that these currents are caused by movements of the atmosphere through heating where auroral displays occur.

“That the atmosphere may have the required properties for the transmission of such currents in its outer limits at a great altitude—designated the ionosphere—was first indicated by the phenomena of terrestrial magnetism itself and independently, many years later, by the propagation of radio waves. The pioneer experiments began in 1925 at the Department, and subsequent developments there have resulted in equipment and technique for more precise investigations of the ionosphere by radio methods. With these methods and investigations, the first rather vague qualitative concepts of the ionized upper atmosphere have progressed to a more sharply defined quantitative concept of several major ionized regions. Each of these, while merging into adjacent regions, has certain specific characteristics, a knowledge of which is fundamental to theories of the magnetic fluctuations. Already the ionosphere observations have supplied some basis for discriminating between certain theories of the regular diurnal fluctuations in terrestrial magnetism and have supplied supporting evidence for the theory proposed to explain magnetic bays.

“While the region of the atmosphere below the ionosphere may play no part in the phenomena of terrestrial magnetism, the phenomena of atmospheric electricity depend vitally upon the processes of ionization and distribution of electric charge in these lower regions. Special observations and studies of formation, mobility, and abundance of various classes of ions and their interrelationships at Washington clearly demonstrate the presence of ions which move in an electric field with velocities between those of the well-known slow- and fast-moving ions, and indicate that both the abundance and mobility of these intermediate ions vary throughout the 24 hours. Opportunity to measure the electric conductivity of the air up to an altitude of 22 km (14 miles) was supplied by the flight of the National Geographic Society-Army Air Corps stratosphere balloon, *Explorer II*, which carried the necessary recording apparatus designed and constructed at the Department. The principal deductions resulting from this flight are: (1) The upper regions of the atmosphere are at 400,000 volts higher potential than the Earth; (2) the conductivity at 60,000 feet is about 100 times as great as at the Earth’s surface; and (3) the previously accepted relationship between air-pressure and recombination of ions does not hold.”

In connection with the investigations conducted by the Department it has been necessary to give attention to the problem of magnetic disturbances, including the field of world-wide magnetic storms. These researches have been conducted in cooperation with Associates of the Institution, including especially Dr. S. Chapman, of London. Assuming that magnetic effects were due to electric cur-



rents flowing in spherical shells concentric with the Earth, current systems were constructed to represent the variations. The external current system was found to have three regions of maximal density, one at the geomagnetic equator and the other two about  $20^\circ$  from each of the geomagnetic poles. Similar maxima were found for the internal system also, the polar maxima being closer to the geomagnetic equator.

A program of studies concerning magnetism in relation to atomic physics was begun by the Department some years ago in the belief that such investigations involve the most basic questions which it seemed possible to frame with reference to the nature of forces underlying the phenomena of magnetism. During the past year, one of the principal experiments described in the original plan was carried out effectively, namely, the study of angular deflections of high-speed protons due to collisions with other protons, as a means of examining the law of interaction of two protons when brought near to each other. The protons involved in these experiments are the nuclei or massive central cores of ordinary hydrogen atoms and together with neutrons form the principal constituents of every atom in the universe.

To quote from the report of the Director, "The Department's special contribution during this report-year has been the measurement of the proton-proton interaction, with some additional important evidence regarding the proton-neutron interaction. Interpreted jointly with other information and calculations it has developed that all of the three possible interactions between these two bodies, the proton-proton, neutron-neutron, and proton-

neutron interactions, have been unambiguously determined by these experiments. Measurements made elsewhere on the scattering and absorption of slow neutrons and on the masses of light nuclei are similarly important, although by themselves such data were quite insufficient to determine the various interactions. From this analysis of the proton-scattering experiments, a remarkable, new simplification of our knowledge of the nature of matter has emerged. Protons and neutrons, the two kinds of massive particles from which all matter is constructed, are shown by these studies to be probably identical in every respect except that of electrical charge. The only differences between the proton-proton interaction and the proton-neutron and neutron-neutron interactions are ascribable to the fact that a proton has the charge of one positive electron in addition to the other properties (mass, spin, magnetic moment, dimensions in space) which are possessed by a neutron.

“Thus the Department’s program, intentionally guided for ten years toward the specific goal of making measurements to elucidate these simplest questions which can be formulated with regard to the basic framework of the laws of matter, has uncovered a beautiful and simple fact of nature which is fundamental to all physical knowledge. Of course, these far-reaching conclusions must yet be confirmed by repetition and extension of the measurements, especially at higher voltages than are available with the Department’s present equipment but, whatever may be the future modification, it appears clear that the contribution made here this year will remain of major importance in any interpretation which may ultimately be made.”

One of the most important contributions of the laboratory coming out of the whole series of studies on atomic magnetism in relation to atomic structure is the recognition of these proton and neutron reactions as expressing a physical force of universal importance. This force was for the first time directly observed and measured in the Department's laboratory during the past year. The force, like gravitation, is a basic characteristic of all material things. It is the attractive force between these primary constituents of matter, protons and neutrons, which binds them together to form the atomic nuclei of all chemical elements.

Although similar to gravitation in the sense that the forces between particles are attractions, these "new" atomic forces are without effect until the particles come exceedingly close to each other, first appearing at a separation of a few ten-millionths of one millionth of an inch. With still closer approach these forces increase very abruptly, and, although they reach a magnitude of approximately a billion-billion-billion-billion times ( $10^{36}$ ), the gravitational attractions between the same particles (ten billion-billion-billion times the weights of the particles), they have been accurately measured in the laboratory. A far-reaching simplification emerged when analysis showed that these attractive forces between proton pairs, between neutron pairs, and between proton and neutron were evidently identical.

Utilization of the high-voltage equipment and technique developed for this program of investigations initiated by the Department in 1926 has thus established the point that over extremely short distances the electric "coulomb" forces, the repulsive forces between like charges, are coun-

teracted by the equivalent of an attractive force. This binding force of atoms is clearly one of the most fundamental forces of nature.

## RESEARCHES OF THE GEOPHYSICAL LABORATORY

Having taken as the objective of investigations the physical and chemical characters in the mass of the inner earth, the conditions faced in this field of study are recognized as extraordinarily difficult because of inability to reach the bulk of the region selected for investigation. But the importance of knowing something of this inner earth upon which we live, both as regards its character and its resources, has made it necessary to devise various modes of research through which adequate information can be secured.

As a well-founded generalization, the investigator in this field begins with acceptance of the idea that all mineral constituents with which we are familiar have had their origin in melted material that has risen from the depths of the earth, and, upon cooling, has given us the solid rocks of the earth's crust. The origin of these materials is then recognized as by way of a molten or igneous state. The problem and situation presented are not, however, reduced to great simplicity by acceptance of this view, for geologists, as the result of long and intensive study of these rocks, find that they present an almost bewildering variety. In discussing this aspect of the question, Dr. Arthur L. Day, Director of the Geophysical Laboratory, refers to this question in his annual report as follows:

"In part this variety is plainly due to the different conditions under which solidification took place, but there

are also fundamental distinctions of chemical and mineral composition. Investigation of the relation of type to type has led to the conclusion that some of this variation arises during the process of consolidation (crystallization). Since the geologist sees only the end-product, it has been realized that a great increase in our knowledge would accrue if mineral melts were studied by laboratory methods and the process of consolidation of these melts were observed under controlled and measured conditions. Studies of equilibrium between crystalline minerals, usually silicates, and their melts have accordingly been a major part of the program of the Geophysical Laboratory.

“To carry out these investigations it has been necessary to develop a special technique which has been improved from time to time as occasion demanded. First studies were concerned with single minerals or simple mixtures. Later it proved possible to extend the work to more complex compositions. Some silicates and mixtures of silicates were found to lend themselves more readily to investigation. In these equilibrium was attained in periods of time measured in hours or even minutes. Other mixtures were found to require days, weeks or even months for the attainment of equilibrium. . . .

“Progress in the study of these silicates which attain equilibrium with great reluctance has been materially aided by finding a method of investigation applicable to the iron silicates. Unlike the sluggish mixtures, the iron silicates attain equilibrium promptly. The difficulty with iron silicates was to find a container that was adequately inert. With the solution of this difficulty and the attainment of significant results upon a number of iron-bearing silicates and their mixtures (Ann. Rept. of Director

1931-32) a method of facilitating the attainment of equilibrium in mixtures of the sluggish type becomes available. It is only necessary to add an iron silicate to such mixtures and it is found that equilibrium can be obtained in reasonably short periods of time. A beginning was made by adding the iron olivine, fayalite, to albite, which ordinarily crystallizes very reluctantly. The result was that albite crystals were readily obtained and the equilibrium relations in all mixtures have now been determined."

In discussion of another phase of the problem of the Geophysical Laboratory concerning the equilibria of rock-forming silicates at atmospheric pressure, the report of Dr. Day discusses this research as follows:

"In this work the liquid phases or solutions have been 'dry melts' wherein the variables concerned are temperature and concentration, and these investigations have been simplified by the fact that, for the conditions of temperature and silicate combinations ordinarily encountered, rock-forming silicates are found to be miscible in all proportions in the liquid state. Any exceptions which have been established . . . lie outside of the temperature region herein considered.

"There is an important field of igneous phenomena manifested in deep-seated activity by pegmatites, ore deposits, intricate replacements of neighboring rock in surface activity by volcanic explosive phenomena and other related features, which is not as yet adequately explored. In order to understand the nature of these manifestations it is necessary to consider the effects of volatile constituents. Furthermore the introduction of a volatile com-

ponent will also act to modify the stability fields of the silicate compounds or minerals.

“To carry out work on silicate systems which include volatile components an entirely new technique must be developed because here pressure becomes an essential variable. Within the last ten years apparatus and technique have been perfected for carrying out such work to pressures of 4000 bars (which corresponds to a depth of nearly 15 km below the surface of the earth), and investigations are being conducted on systems of rock-forming silicates with water included as a component.”

In another aspect of the work of the Laboratory there has been effort to secure data regarding the earth from portions of the surface which have been difficult of access. One of the most critical areas has been the bottom of the deep sea, where materials accumulated represent both a series of conditions quite different from those which we know commonly upon the land, and where the record of accumulation may have exceptional value. This situation is described in the report as follows:

“The interest of this Laboratory was focused on the ocean-bottom and its geophysical significance when it was called upon to make a series of determinations of the radium content of the bottom samples obtained by the yacht *Carnegie* on its last cruise. These 28 samples, together with another suite of 28 taken by the *Challenger* and *Princess Alice II* and tested for radium by Dr. Hans Pettersson, demonstrated the fact that the sediments of the ocean-bottom possess a far greater concentration of radium than do any class of rocks, igneous or sedimentary,

as yet examined on land. This fact has far-reaching geophysical connotations.

“Nearly all the samples, so far examined, of the ocean-bottom have been ‘grab samples,’ *i.e.*, a few cubic centimeters of material scraped up from the surface of the bottom. They yielded no knowledge of what lay below—no perspective of sequence or time. In view of the vast area represented by the ocean-bottom and its probable antiquity, some sort of undisturbed core sample was most urgently desired.

“The geophysical aspect is not the only one requiring knowledge of what lies below the topmost surface of the bottom of the ocean. For general oceanography it is of the utmost importance in view of the fact that seventy-two per cent of the surface area of the earth is covered by the ocean. The material lying, layer upon layer, in the bottom constitutes the repository of the historical record of this ocean. This record has been accumulating throughout many ages and during many changes in the water above. What has happened in this water is recorded by the remains of many minute organisms which lived and died and evolved into various forms within it, and whose skeletons now constitute much of the accumulated material of the bottom. . . .

“Far out from land in the undisturbed depths of the open ocean this record has accumulated very slowly, so that a few feet of depth may represent a very long interval of time. Therefore, if we could bring up a vertical section of several feet of this bottom, in its original undisturbed condition, we might read the history of ocean events as the geologist deciphers the record in the rocks.



"The need of such samples has been felt for many years and many devices to secure them have been tried. Recently an apparatus has been developed which has obtained such 'cores' up to ten feet in length and containing sufficient material for a very comprehensive study.

"The particular value of these samples, over previous ones, is that the material is available for study in the undisturbed sequence existing in the bottom, and consequently a record of succeeding events can be obtained from it. Particular strata may be traced over wide areas and a knowledge of the succession of events in terms of time and extent may be obtained.

"The only record of the history of the existing ocean lies buried in its bottom. Whether this record will be easy or difficult to decipher, voluminous or meager, remains to be ascertained, but whatever its nature it is now accessible through these core samples."

Studies of material from the ocean bottom which were begun by Dr. Charles S. Piggott, of the Geophysical Laboratory in examination of samples secured by the ship *Carnegie* on its last cruise have been extended in a very significant way in the past year through opportunity offered by the Woods Hole Oceanographic Station and the Western Union Telegraph Company. Through the courtesy of the Western Union Telegraph Company Dr. Piggott was able to secure samples from a considerable range of sea bottom in the Atlantic. This was made possible by invitation to accompany the cable ship *Lord Kelvin* in the summer of 1936. The samples secured ranged from depths of 700 fathoms ( $4/5$  of a mile) down to 2640 fathoms (3 miles). The cores obtained have a diameter

of two inches and range up to ten feet in length, most of the specimens being of a length much beyond that which has heretofore been available for these studies.

The continuing relation of Dr. Day to seismological studies, through his Chairmanship of the Advisory Committee in Seismology and guidance of the Seismological Laboratory in Pasadena, has brought into the discussion another phase of research which has had large significance in interpretation of the inner earth.

As is true in all investigations of such a type, the close examination of general geophysical problems has brought out the need for more intensive work in the fundamental fields of physics and chemistry, so that the Laboratory has become an important contributor, not merely in the application of these sciences to the study of the earth, but to the sum of our knowledge on physics and chemistry in the broader sense.

Retirement of Dr. Arthur L. Day from active direction of the Geophysical Laboratory within this year calls particular attention to the extraordinary program and large volume of contribution from the work of this unique organization. The researches of the Geophysical Laboratory represent in a measure the extension, on a broader basis, of investigations begun by Dr. Day as a member of the staff of the United States Geological Survey. The founding of the Geophysical Laboratory gave opportunity for development, as one program, of special apparatus for checking in the laboratory the types of reactions which were assumed to take place naturally in the mass of the earth. These experiments, reaching to high pressures and

high temperatures, have contributed very greatly to our knowledge of this subject by use of the laboratory method. They have made it possible to study, under control, conditions existing at the depth of many miles in the earth's crust. Correlated with laboratory studies, recognized as physics and chemistry, there has been carried out also an extensive program of field work related partly to the phenomena of active volcanoes and hot springs, and partly to the study of volcanism as represented in the geological history of past ages.

In leaving the active direction of the Geophysical Laboratory Dr. Day has been invited to aid in organizing a cooperative research with investigators in New Zealand covering questions involved in study of the hot spring phenomena of that region in their relation to seismology, volcanology, and problems of geology. It is important to note that the contribution of Dr. Day in this significant work brings to bear the accumulated experience not only from many years of his personal work, but of the entire Geophysical Laboratory staff and associated investigators in this country. With the outlining of a program for research in New Zealand, science arrives at a stage of rounding out investigations on the major hot spring phenomena of the world, and from these researches there is certain to come not only a clarification of our knowledge on these problems specifically but with respect also to the nature of the earth more broadly considered.

## SEISMOLOGICAL RESEARCH

The annual report of the Advisory Committee in Seismology as transmitted by Dr. Arthur L. Day is a record of continually increasing activity in research at the Laboratory in Pasadena. The foundation was laid for this work in many years of careful study on program and in development of new types of instruments. The research has brought abundant fruit in the study of seismic activity on the west coast in recent years. The importance of results from investigations at the Laboratory has been increased through cooperation with other institutions such as Stanford University, the University of California, and the Coast and Geodetic Survey of the Federal Government.

In attempting to obtain an understanding of what actually takes place in movement of the earth's crust it has been necessary to give special attention not only to seismic activity in the physical sense, but to the relation of such movements to structure of the earth's crust, and to the history of crustal movement in geological time. Practical contribution from the Laboratory is made through determining the location or points of origin of earthquakes with reference to local geological structures, more specifically to lines of fracture. It has been important also to know not only the structure of the rocks, but the materials involved, if there is to be adequate understanding of the relation of seismic movement to engineering effect in the human sense.

One extremely important contribution from the seismological studies at Pasadena has been made possible by the group of sub-stations spread across the Coast Range region of California, giving an adequate and accurately

timed record of the effect in any movement at each of these points of observation. By use of the data thus secured it is possible to form an estimate not only of the location with reference to the surface, but also as to the depth and the character of the movement. For purposes of study, large value has been found in the record of small shocks which are humanly not recognized as of significance, but which delicate instruments record and which modern science interprets. It is noted, for example, in the report of the Committee, that the Laboratory has record in the twelve months from May 1935 to April 1936, inclusive, of 3901 local disturbances. Of this number it has been practicable to make location of 559 independent shocks, together with 152 well-located small after-shocks.

One of the important contributions from recent studies has been the evidence that the sources of local shocks seem to cluster along known lines of fracture or faults. Thus far it appears that the shocks of considerable importance which have been located have all originated along zones of faulting.

On the whole, the developments which have come out of the program of seismological research in relation to geology and geophysics have furnished a contribution of the first order of importance, both with relation to a scientific knowledge of our environment and with reference to applicability of the data to human engineering use in the protection of the property and lives of men.

### PLANT BIOLOGY

The Division of Plant Biology was organized with reference to a broad range of problems in the field of plant biology extending from study of basic chemico-physical

processes such as photosynthesis on through the range of biological problems to the great group of studies concerned with relation between heredity and environment. As now constituted it forms an effective and flexible unit with the elements of its program well defined and well articulated. An outline of problems of the Division as presented in the annual report for the past year states this problem as follows:

“The investigations which are being pursued by the various sections composing the Division of Plant Biology are in principle of two sorts. There are investigations representing intensive and specialized study of individual functions and components of plants. Such investigations are designed to analyze particular activities, the agents or forces which produce these and the factors which influence them. These efforts concern themselves primarily with the chemistry of the materials of which the plant is composed and the chemical changes involved in some of the more important activities characteristic of plant life. Another group of investigations concerns itself with attempts to synthesize the various elements which enter into the life of all vegetation or of plant aggregations and societies. They constitute attempts to determine the interrelationship and interplay of force which result in the vegetation on the earth today and the development of concepts as to the manner in which it has changed during geological periods. These investigations deal primarily with the interplay of forces within the organism and of the environment to which it is exposed. These two lines of investigation, in a sense, represent opposite approaches to the same or closely allied problems, the one specialized

and analytical, the other reciprocal and synthetic. Both have yielded results bearing directly on fundamental processes occurring within all plants, on environmental influences affecting form and function, and on the rhythms and periodicities which are an expression of the interplay of these forces.

“Within recent years there have been some indications that agriculture may be entering upon a period of fundamental change in practise, which may prove to be quite as drastic and far reaching as occurred in manufacture and transportation as the result of the industrial revolution of a century ago. The real issues in this great readjustment have not yet been clarified and are in no small measure obscured and confused by the traditional reluctance of agriculture to give way to a new order, because of the complex of social, economic and political traditions which are involved. But to a large extent economic and political expressions are but symptoms of more fundamental forces. Economic fluctuations in regard to agriculture are not unrelated to the great complex of relationships between weather, soil and the growth of plants. The living plant and all of its products represent a dynamic, reciprocal relationship between the functioning of the organism and its environment. The reaction of plant to environment is not haphazard; complex though it be, it reveals on careful study, certain dominant regularities. So also climate, and the whole environmental complex, are objective phenomena, which lend themselves to patient, orderly scientific research.

“There can be little doubt but that one element in any rational readjustment of methods of agriculture must be the knowledge of the functioning of plants and of their re-

lation to their environment. As a matter of fact, this scientific element has received less popular attention in a consideration of the problem than other more conspicuous, though less fundamental, aspects. Out of the patient accumulation of scientific information concerning plants are emerging new methods of growing crops and new uses of the products, which are not only important as foodstuffs, but which are potentially of great significance to industry. It is in the very nature of scientific development that its first steps are cautious and unobtrusive, that it does not impress itself upon the unimaginative public mind, preoccupied with immediate economic and political subjects. But the consequences of such scientific development are none the less potent and appear surprising to unprepared minds. The importance of such developments can hardly be overemphasized, and it is quite conceivable that they will be directly determinative in case any readjustment of agriculture is to follow. Certain it is that in the great balancing of forces which determine a movement of this magnitude, scientific facts concerning the central element involved, namely the living plant, will play a rôle as decisive as the economic and social factors which are dependent upon it.

“What contributions to this problem can be made by an agency such as the Carnegie Institution is too large a question to be discussed in the compass of this report. But a careful study of the many types of institutions and organizations whose combined efforts are providing an ever increasing body of essential information on this subject has led to the formulation of certain ideas and policies which have been applied within the Division of Plant Biology. Since the inception of the Institution the policy ‘to en-



courage in the broadest and most liberal manner investigation, research and discovery, and the application of knowledge to the improvement of mankind' has made possible the intensive investigation of certain fundamental problems over extended periods of time. It has thus been possible to concentrate effort on relatively few projects which seemed to be of basic importance, and to pursue these intensively, unhampered by pressure for immediate results or applications. As a matter of experience, the applications of the discovery of fundamental facts follow relatively rapidly and almost automatically, there being many agencies and facilities, with vast financial support, organized to try out on a large scale and put into practise any new idea."

In the subject of basic investigations in photosynthesis, or the fundamental chemical reactions of the leaf which take place in the presence of light, the researches of the Division have given us a picture of this field representing many avenues of investigation. Especially important is it to note that in this section of work of the Division of Plant Biology there has been carried out one of the most careful known analyses of the problem of photosynthesis and the modes of attack. With reference to this question it is interesting to quote from the annual report of Dr. Spoehr, Chairman of the Division, as follows:

"It seems clear that the formulation of hypotheses to guide experimental study of the process is in no small measure restricted by our limited knowledge of the photosynthetic apparatus of the living leaf. Biochemical investigations can contribute materially toward a better understanding of the materials and physical factors of

this apparatus, and the investigations carried out in this Division have for some time had this as their main objective. These have been concerned chiefly with intensive studies (1) of the carotenoid pigments, (2) of the primary reactant with carbon dioxide, and (3) of the conditions which affect enzyme action in chlorophyll-bearing cells."

Another phase of the subject, concerning especially the absorption of carbon dioxide by the unilluminated leaf is described as follows in the report:

"It has been realized for a long time that the absorption of carbon dioxide from the surrounding medium by the chlorophyll-bearing tissue constitutes the first step in the photosynthetic process and that there must exist some mechanism or substance by means of which this is accomplished. The concentration of carbon dioxide in the air is very small; it is remarkable that the leaf can absorb and assimilate so rapidly such relatively large amounts of this gas. None of the hypotheses thus far proposed to account for this phase of the phenomenon of photosynthesis have proven satisfactory, and it has long been apparent that this feature of the photosynthetic apparatus is but poorly understood. An investigation of the carbon dioxide absorbing capacity of unilluminated leaves was undertaken in this laboratory some years ago, and during the past year this investigation has been resumed by the use of different methods."

The studies on experimental taxonomy conducted in the Division by Dr. Clausen, Dr. Keck, and Mr. Hiesey have led to the development of an extremely important point of view concerning not merely taxonomy, but the general

field of evolution and relationships in plants. A statement of this question is outlined in the report, as follows:

“These investigations, designed to attack the problem of natural relationship on an experimental basis and that of natural evolution by analytical and synthetical methods, entered a new phase in 1932 by the addition of cytogenetical methods and of more intensive and extensive studies in standard environment gardens. It was soon found that the plant groups, which Dr. Hall had selected for the work, were admirably suited for the new approaches. But it became equally evident that this new departure required a revision of principles and of existing criteria of relationship. Consequently, a complete re-examination and re-cultivation of the materials, especially of the numerous races of *Madinæ* species, were necessary.

“The very existence of natural systematic units has been doubted by many biologists. It has been necessary, therefore, to show by experiment that groups of individuals are separated not mainly by conventional characters selected by taxonomists, but, in addition, by mechanisms inherent in their own structure that tend to keep them pure. This has put the species concept on an objective rather than a subjective basis. The controversial question of the importance of hybridization for the evolution of species has also been put to experimental tests.

“Thus, major items of the present investigations have become: the outlining of principles and methods for a new discipline of experimental taxonomy, experiments on the natural species and other systematic units exploring

their factual bases and characteristics, study of processes active in the evolution of species, and, as a result from these studies, the monographic treatment of plant groups.”

This consideration leads naturally into the old problem of the nature of species, which has come to have new significance in the work of this Division and is discussed in the report in the following statement:

“Extensive investigations have now tested the theories as to what constitutes a species. The work has shown that it is possible to give a fairly objective delimitation and classification of species based upon experiments rather than upon speculation, because there is a natural basis for species and other systematic units, which can be explored. Studies on systematic units of various order have revealed the following general trends.

“Species are separated by genetic barriers of various degree and effect. Their hybrids are either partially or completely sterile, or, if fertile, most of the second generation shows a remarkable lack of vigor and would be eliminated under natural conditions. . . .

“Characteristic of species as they exist in nature is that the genes controlling their morphology, physiology and development form an intricately balanced system ensuring inner developmental harmony and also harmony with their natural environment. Once a species is taken out of that environment the balance is somewhat disturbed, but the inner balance between various genes pulling in different directions still exists. Under natural conditions this balance is perpetuated from generation to generation through the chromosomal mechanism ensuring

a relatively faithful reproduction of the genic structure for the species, which apparently is homozygous for all specifically essential genes."

In the work of the Division one of the principal aids or instruments for research on relationships has been the group of transplant stations ranging across the State of California to Timberline station in the Sierra. This is outlined in the following statement from the report:

"The accumulated transplant data furnish excellent background for studies planned to reveal interrelationships between morphological, cytogenetic, anatomical and physiological characteristics of plant forms from different environments. Correlations between the morphology of closely related forms within complex species and features of habitats which they occupy give assurance that new understanding of plant relationships and of processes governing plant distribution may be realized through coordinated investigations from different points of view on the same plant materials.

"Steps toward intensification of the transplant experiments along these lines are gradually being undertaken. Material from transplants is being preserved for studies in comparative anatomy of races of the same species which originally came from different elevations, and for anatomical comparisons of clone-members of individuals transplanted to the Stanford, Mather, and Timberline stations. Consideration is being given to the development of methods for measuring certain physiological characteristics of transplants while growing undisturbed in gardens. A comparative study of some of these physiological processes may lead to the discovery of at least a

few of the differences in function which make possible survival of given types in certain environments. With this end in view, Dr. Mallery of the Desert Laboratory is continuing studies on the measurement of osmotic concentrations of expressed plant saps with transplant materials. . . .”

In connection with the ecological studies, special mention has been made in the report of the work of Dr. Clements in its application to the ecological methods and processes needed as a basis for study of a conservation program for the western region of the United States. Statement of one aspect of this problem is noted in the report, as follows:

“The application of ecological methods and processes to the national projects in conservation has been broadened and deepened during the past year. Especial consideration has been paid to the process of natural recovery, which is essentially a matter of secondary succession. The course of this is quite different in abandoned fields from that in pasture and range, and it differs again in its details from one division of climate and climax to another. However, its two major features are universal, in that disturbance or destruction must first cease more or less completely and movement of populations to or toward the climax be resumed. Artificial succession or regeneration is similar in character, but possesses the great advantage that an adequate access of seed is assured. It profits much and often decisively also by telescoping the succession into one or two stages as a rule, by selecting the most desirable dominants for the particular site, and by using mechanical

methods of preparing a seed-bed and insuring a larger supply of soil moisture.”

The study by Dr. A. E. Douglass, concerned with questions relating to cycles in climate, has advanced rapidly in the past year, the result being the bringing of a considerable part of the work on his most important research to publication. The study of long chronologies by Dr. Douglass, as outlined in the following quotation from the Year Book report, gives an illustration of the method of approach in this question:

“The extension of our long Arizona chronology back to A. D. 11 was referred to in the 1934 report. It was strengthened further in 1935 and with the more intensive examination of the specimens now appears almost certainly free from errors of identity. When the ring records of some hundreds of specimens are massed together in a plot, showing their extension in time, there are evident certain banks of years thickly covered by specimens, and between these banks the intervening points are represented by comparatively few records. This banking of records, viewed in one way, points back to the four large floating sequences with which the writer struggled in first extending the long chronology back before 1300. The less well-filled points of contact between the banks have historic and climatic significance. One of them was at the time of the great drouth in the late 1200’s and was caused by it. This drouth was a calamity to the peoples living in the dry Southwest and was connected with, we think, the profound change in cultures from Pueblo III to Pueblo IV. Another occurred in the early 1100’s, in the latter part of the ‘Classical Period’; a third was near

700, probably at the time the 'Basket Makers' were taking on Pueblo culture; and a fourth was in the early 500's, at a time not yet expressed in culture change. The identification of building dates as early as A. D. 348 and 352 and other times in that century make it seem worth while to attempt the special preservation and possibly the restoration of some of those early settlements. While these points of jointure have fewer specimens covering them, they present no cases of doubt as to the continuity of years across them. This is because they are usually drouth periods and the quality of the records that pass through them is very high. However, for the sake of uniformity in the whole sequence one desires to add other dated records of all types at these particular points."

As is noted in the report of the Division for the past year, study of the desert, such as is conducted at the Desert Laboratory at Tucson, has much in common with study of the sea. In both cases life is sharply limited by specific conditions which have similar influence over very wide areas. In the sea, adaptation to aquatic life means not only methods of locomotion, but involves relation to the securing of food, to respiration, and to temperature. In the desert the limitations of humidity may be sharp, and at the same time the range between periods, as winter and summer, may be wide.

Studies carried on at the Desert Laboratory during the past year have continued to emphasize especially examination of the broader problems presented by field work in the area extending from Tucson into the regions about the Gulf of California. These researches represent in many respects the type of investigation which was visual-



ized at the time the Laboratory was founded. Excursions which have been made into various regions of botany by way of the Desert Laboratory have all been important as touching questions of structure, physiology, and classification. At the same time it has been desirable to bring back to special consideration the larger question concerning the influence of the desert upon life, and what the human values are which may be available in this type of environment.

The contributions of the past year in Desert Laboratory research have included important records of field and laboratory studies, and also interpretative articles, such as that represented in the paper by Dr. Shreve entitled "The Desert and Its Life."

### ANIMAL BIOLOGY

The divisional organization of Animal Biology includes researches primarily concerned with anatomy, embryology, physiology, heredity, and evolution of animals. So far as possible the several projects are located where the work can be conducted to best advantage. The principal groups included are the Nutrition Laboratory in Boston; the Department of Genetics including the Station for Experimental Evolution and the Eugenics Record Office at Cold Spring Harbor; the Department of Embryology in Baltimore; and the Tortugas Marine Laboratory on Loggerhead Key, Florida.

In making record of activities in the Division during the past year, it is important to note the increasing effectiveness of cooperation in research among the several groups, as also between these groups and other departments of the Institution. Similarly it is desirable to note

the close cooperation and sympathetic development of certain projects involving other research institutions and universities. Recognizing the danger of emphasizing researches as important just because they may be cooperative, it is still worth while to point out that such relations have made desirable, for example, cooperation between the group of students engaged in study of the gene at Cold Spring Harbor and the investigators concerned with high voltage radiation in atomic research at the Department of Terrestrial Magnetism. It happens that this particular type of relation in activity is important because it makes possible a study of certain abnormalities produced by irradiation which may have bearing upon critical questions in research on experimental evolution.

Continuing of conferences by the several groups in this Division, meeting in turn at the different laboratories, has brought opportunity for discussion of researches from a sufficiently wide range of viewpoints to give increased value to the results from individual investigations. It is important to make record of the type of activity that takes place in one of these conferences by listing the titles of the following out of a group of papers presented at a recent meeting:

Fewer Pituitary Hormones for Total Pituitary Function.

The Problem of Optimum Calcium Intake.

Modification of Environment and Malignant Expression.

Geographical Distribution of Prime Types in *Datura Stramonium*.

Use of Salivary Chromosomes in Genetic Research with *Drosophila*.

The interlocking of activities in the Embryological Laboratory and those at the Department of Genetics continues to present some of the most interesting possibilities for advance in the research of this Division. The colony of macaque monkeys at the Embryological Laboratory has furnished extraordinary opportunity for study of every stage in the reproduction cycle, and gives us for the first time much new information which has immediate application in study of the development in human beings. Not only has there been secured practically every stage in the development, thus permitting accurate observation as to what takes place and how it takes place in these cycles, but there has been also an extraordinary advance of knowledge regarding the control of factors, involving among other features the endocrine glands and their relation to development.

Studies on influence of the endocrines has in the past year, as in earlier stages in the history of these investigations, shown close relation to certain aspects of the endocrine research conducted by Dr. Riddle at the Department of Genetics. This interesting interlock of researches has its importance both with reference to the reproductive cycle and to the relation of the early stages of development, in the sense of mechanism of heredity, to the later stages of development in which growth of the individual comes in considerable measure to be controlled by the endocrines.

The work of the Embryological Laboratory has in the past year thrown much light on one of the most fundamental of all biological problems, namely, development of the layers which are defined in early stages of the embryo. This contribution seems to have direct influence upon the views of biology relating to this theory.

In another direction studies in the field of embryology have given us more definite evidence concerning factors involved in origin of tumors. It has been shown in this connection that if tumor cells from one strain of mice are used to induce a foreign-protein sensitivity in another strain, the resistance of this other strain breaks down, and tumors may develop in some of the individuals. This makes it clear that there are at least two factors involved in the origin of tumors: one the permanently altered cell, and the other the environment in which the cell must exist. In the experiments the unfavorable host-environment is ordered so as to permit growth of the malignant cell.

Among anatomical studies conducted, it is found that height-weight charts, if they are used as guides to normal development, must be constructed separately for Navajo children and Dutch white children as compared with American children in general. Research on the problem of dental caries among four races varying in habits and kinds of food indicates that heredity is a large factor in the occurrence of sound teeth. Studies of certain mental characteristics have been made comparing Indian and Negro and White children covering both ordinary activities and such functions as art appreciation.

In the Department of Genetics there has been fortunate correlation of investigations concerning certain factors relating both to plants and to animals. It is noted as a matter of special interest in study of the fruit fly that the natural mutability of wild Florida inbred stocks is much higher than any heretofore studied. Experiments with these stocks indicate that the factor responsible for the increased mutability is nuclear and is probably a single gene. Furthermore, the effect on other genes is not limited

to any single one, although it influences some more readily than others.

In study of the wide field represented by plant material at the Department of Genetics interesting results have been secured through the investigation of variation in the rate of mutation by ageing of seeds through injury to them by heat and moisture, a similar treatment being extended also to pollen of the plants. The mutation rate is found to be higher following pollen treatment than is true for seed treatment. When pollen was treated mutation was seen in 15 per cent of 300 plants tested.

In study of the movements of those important but minute elements of heredity known as the chromosomes, the conclusion has been reached that the essential mechanism in mitotic movements is initiated by several agents, any one of which can bring about the necessary chromosome activities where, due to the widely varying conditions, others can not act.

The studies of leukemia, both with relation to problems of heredity and environment, have increased in importance and include investigations on induced resistance and comparison of the resistance following repeated small doses of leukemic cells and that following embryo tissue treatments. Further direct evidence has been obtained on the nature of the injurious effects of leukemic cells in that it is found that these malignant cells exert a depressing effect on the metabolism of normal tissue.

The studies in endocrinology which have been centered for a time upon the influence of prolactin, the milk-producing hormone, have been extended widely. It is found that in reality nine different responses develop through use of prolactin. The conclusion is reached that the

hormones of the anterior lobe of the hypophysis are not numerous, probably only three or four, but that they are very versatile, and their analysis requires the most careful technique of experienced investigators provided with the best facilities.

In the field of nutrition occupied especially by Dr. Benedict in his study of metabolism, the advance made in the past year can perhaps best be stated by the following quotation from the report of Dr. Streeter, Chairman of the Division:

“Because of the meticulous care and ultra-refinement of the technique under which basal metabolism studies have been conducted at the Nutrition Laboratory and because of the unique standards, which have been established under such favorable circumstances, the laboratory has found itself associated with a wide variety of cooperative endeavors where detailed reliability is essential. The researches for the year thus cover several fields of investigation and involve a number of non-resident workers. The unusually profitable cooperative research with Professor Ritzman has continued and further observations have been made on large domestic animals. Various factors that determine basal metabolism have been studied, such as season, lactation, sex and the constitution or type of the individual animal. In cooperation with Dr. Bensley of the Montreal General Hospital important observations have been made on heat elimination of the human subject after the ingestion of sugars, with results compared as obtained by direct and indirect calorimetry. The study was extended to include respiratory exchange, alveolar air and blood-lactic acid after such ingestion. In cooperation with Dr. Root and Dr. White a study has been made

of the prevention of respiratory failure by the use of a helium oxygen mixture. A similar study has been made with Dr. Barach for the relief of dyspnea. Studies have continued jointly with the Department of Embryology on metabolism in the macaque monkey. The work with Professor Sherman on old age in rats has been completed. Cooperating with workers in foreign countries, metabolism observations have been obtained for natives in Hawaii, Samoa and China."

One of the most distinguished collaborators in research activities has been taken from us in the last year through the death of Professor Lafayette B. Mendel, of Yale University. Dr. Mendel's investigations in the field of nutrition, with its many relations to chemistry of the cell, had significant touch with studies on the nature of the cell and the nutritive properties of proteins conducted by the late Dr. Thomas B. Osborne at the Connecticut Agricultural Experiment Station. A very significant part of the wide range of problems in nutritive properties of some of the most important foods has developed from these researches. It was in association with these studies that much of present-day knowledge concerning the meaning of vitamins developed. The work of Dr. Mendel and Dr. Osborne, taken together, has been one of the most important factors in scientific research on foods and the application of this knowledge in human life.

### HISTORICAL RESEARCH

The Division of Historical Research was organized with a view both to furthering contribution of new materials in several special phases of research on human experience and to clarification of vision over the whole field of history.

It was evident that history must have the results of intensive study on a wide range of individual and group experiences, and at the same time clear understanding regarding relation of these events to each other in time and in space. It was recognized as well that while sharp limitation in a field of study seems at times to bring relatively high illumination, such circumscribing of limits may prevent discovery of relationships with which acquaintance is necessary if satisfactory interpretation is to be obtained.

The form of organization in the Division has permitted at the same time concentrated attack upon special problems such as the early history of the Maya and the consideration of major questions relating to the advance of civilization. In the past year the several sections of the Division have made significant progress in the study of special fields in archæology of the southwest, evolution of Maya culture, problems in early history of the United States, the history of science, and other subjects. There has also been progress by the whole Division in understanding of methods by which it may be possible to establish the most effective relation between or among historical subjects appearing widely separate, but actually having close relation.

While there is much discussion concerning relation between the methods of history as touching man and those used in study of events involving other materials in the world about us, there can be no doubt that advance of knowledge and interest in historical aspects of science represented in archæology, palæontology, historical geology, and the theory of evolution, has had important influence on the attitude of investigators toward the problem of history as relating to man alone.



While there is no question concerning the presence of factors in human history, such as the influence of choice and the cumulative values of culture, that are absent in study of other types of sequences, this does not diminish the need for study of sequences in human history with a view to securing information as to procedure or laws expressed in movement or change. It is to be noted that certain differences between human history based upon events as recorded by man and history expressing the recording of events by natural processes do not arise from difference in the causes or sources of action, but from difference in the manner of recording the data.

The program of study devoted to evolution of the Maya culture or civilization as worked out by the Division of Historical Research has been an unusually difficult problem by reason of isolation both in the sense of time and of space. Although the Maya and their culture were in existence when the Spaniards entered Middle America, the civilization was decadent, and the remnants have since largely disappeared. The story of this adventure in culture is therefore cut off from us quite sharply.

If, as is assumed by most students, the Maya culture is mainly if not entirely an American product, it is then largely separated from other cultures geographically. In this respect the study of that phase of civilization presents a problem quite different from many that we investigate in the Old World, where there is a wider band of connection with the present.

The unusual isolation of the Maya means that in undertaking study of this particular human experiment one seems almost to attempt the understanding of an impor-

tant civilization through study of heaps of stones in ruins largely covered and torn apart by the jungle.

The fact that so many modes of approach and so many disciplines have been found essential in study of the Maya problem, directs attention to the complexity of any or all historical questions. In every case, what has taken place is the result of a great number of forces and influences. In few, if any, instances is the problem really simple, or at least it is not so simple as it appears. May it not be then that the story of other peoples and cultures should be reviewed in somewhat the same manner? Is it not desirable, as is done in many investigations, to give attention to the wider range of factors concerned in situations touching major historical problems of great civilizations?

The values of history are primarily for the present and future. One may note also that history benefits the past as well by giving values to things behind us, which might otherwise remain in oblivion when their contribution has continuing importance. The great significance of history being for the living present and the growing future, it is desirable that whatever there is of value in materials or methods coming from any source be given opportunity for application in situations where its truths may be utilized. It is important that for an advancing civilization, offering exceptional opportunity to formulate and test modes of life and growth, there be found means for use of the data coming from other adventures in civilization.

Especially desirable is it to have means of comparison and self-measurement for a people such as ours, with limited historical background relating to its present environment, and showing a tendency to exaggerate the im-

portance of contribution in this age as compared with the vast bulk of experience which the world has accumulated.

Since one of the outstanding features in the program of historical research of the Institution is found in the focusing of an especially wide range of interests concerned with the problems, broad contact with agencies of many types is required. No better method of stating this case can be used than by quoting from the report of the Division of Historical Research with special reference to the co-operative program in the Section of Aboriginal American History which is outlined as follows:

“In the correlated undertakings of the Section of Aboriginal American History there has been received invaluable cooperation from other departments of Carnegie Institution, from many outside agencies, and from individuals. The Department of Genetics has supported the extremely significant work of its staff member, Dr. Steggerda, on physical anthropology of the living Maya, on Yucatecan agronomy, and on various aspects of present-day Maya life. The experts of the Geophysical Laboratory have given generously of their time to forward Miss Shepard’s technological studies of Southwestern and Maya ceramics. The Department of Terrestrial Magnetism has trained the Section’s field men in the taking of astronomical observations for determination of the geographical location of ruins, has loaned equipment, and has checked results. The Nutrition Laboratory has made many analyses of Maya foods and Dr. Benedict has collaborated with Dr. Steggerda in publications upon the basal metabolism and the diet of the Maya. The Division of Plant Biology, by kindness of Dr. Shreve of the Desert

Laboratory, has made identifications for the Chairman of plant products from ancient dwellings in Arizona and New Mexico.

"The University of Michigan biological survey of Central America, carried on at its own expense, is contributing a large amount of information concerning the zoology and botany of the Maya area. One result of this investigation is a series of botanical papers, published by the Institution under the editorship of Messrs. Bartlett and Lundell. Duke University, through Drs. Pearse and Hall, is contributing to knowledge of environment through researches upon the fauna of the inland waters of Yucatan. The United States Bureau of Plant Industry has donated the services of Messrs. Collins and Kempton, and the United Fruit Company those of Mr. Popenoe, for the investigations upon Maya agronomy and the genetics of maize.

"With the University of Chicago there has for some years been in effect an arrangement whereby members of its staff have served as half- or part-time employees of the Institution. In this way the Division has benefited by the wise and energetic direction of its ethnological program by Dr. Redfield, Dean of Social Sciences in the University; and has been able to carry on a survey of the Maya linguistic stock by Dr. Andrade. Also by a part-time arrangement, Miss Shepard, of the Laboratory of Anthropology, has worked on ceramic technology. The Peabody Museum of Harvard University and the Laboratory of Anthropology have supplied quarters to many Division investigators; and the splendid Maya libraries of the Peabody Museum and the Department of Middle American Research of Tulane University have been placed unre-

servedly at our disposition. Both the last-named institutions and the Museum of the University of Pennsylvania have permitted study and even publication of unique manuscripts.

"Contributions by individuals have been of equal importance. Dr. G. C. Shattuck, of the Harvard School of Public Health, has not only donated his time for field work bearing upon problems of disease, but has assumed the expense of preparing his medical monographs on Yucatan and Guatemala for the press. Mr. Lawrence Roys has personally defrayed the cost of several trips to Yucatan to study the structural features of Maya architecture; Mr. Ralph L. Roys and Mr. Robert E. Smith, who receive purely nominal salaries, are carrying on key investigations of post-Conquest Maya documents and of Uaxactun pottery, respectively. Lastly, Miss Lila O'Neale, of the University of California, has devoted her sabbatical year to research upon Guatemalan textiles.

"Scientific activity in foreign countries naturally requires cooperation of governments concerned. In Mexico, Guatemala, and Honduras, the Institution has received most effective aid from the authorities: Sr. Toro, Director of the Department of Monuments of Mexico, and Sr. Ignacio Marquina, of the Section of pre-Hispanic Monuments; Lic. Antonio Villacorta, Secretary of Public Education of Guatemala, and Sr. Carlos Villacorta, Director of the Guatemala National Museum; and Dr. Jesus Rodriguez, Secretary of Public Education of Honduras. They have all striven to facilitate the work of the Institution. The government of Honduras has participated actively in the excavation at Copan, defraying all costs of labor and of the transportation of supplies."

Among the significant advances in work of this Division during the last year were investigations at Uaxactun in the Peten region of Guatemala, where the eleventh season's work was carried on in the past summer under direction of A. Ledyard Smith. The discoveries at this extraordinary site have brought out a large number of buildings, an especially important sequence of cultural stages, and much information relative to architecture and to art, making altogether a contribution of outstanding significance concerning the earlier stages in history of the Maya.

In the past year another extremely important site with especially interesting historical data has been obtained in a region of peculiar interest at Kaminal-juju on the outskirts of Guatemala City. In addition to excavations carried on in this general region in 1935, investigation was conducted in the past year at the suggestion of Lic. Antonio Villacorta, Minister of Public Education of Guatemala. The structure uncovered consisted of several pyramids one over the other. The operation of excavation brought to light unusually valuable architectural and ceramic materials. Three tombs were also discovered immediately to the east of this mound. In these burials were skeletons of persons of importance, associated with lavish offerings, implements, pottery, and jadeite ornaments. Some of the pottery appears to bear close resemblance to that of Uaxactun, some to that of Teotihuacan in Mexico.

Cooperative study of the great site of Copan, in Honduras, has been carried on during the past season by Mr. Gustav Strómsvik, resulting in very important advances in knowledge of this area, as also in protection of

these relics of exceptional interest among the sites of Middle America. Cooperation by the government of Honduras in this work has been of the highest value, and made possible what has been accomplished in this large work. One of the problems of immediate importance involved the turning of the Copan River away from the site. For centuries this stream, subject to violent summer floods, had been undermining and washing away large parts of the ruins. Serious damage had been done to the enormous central group known as the Acropolis, and the protection of this area was essential. In 1935 it was decided to open a canal across an ox-bow bend, throwing the river into a new channel. This work has been done by the government of Honduras under the supervision of Colonel Sans.

As a part of the program at Copan extensive tunneling operations in the Acropolis have been conducted as the first necessary steps in study of this great complex, which grew to its present size by the piling of building upon building. The story of these preliminary operations and the advances in scientific knowledge made through this work will appear in full in the report of the Division in the annual Year Book.

Other activities of this Section have involved comparative studies based upon an architectural survey and the data based upon a ceramic survey of various regions investigated in recent years. The ethnological and social research of Professor Redfield, Mr. Tax, Mr. Hanson, and Mr. Villa has also contributed material of the first order of interest. The linguistic investigations carried on by Manuel J. Andrade represent another phase of the study of this region, which fits in a striking way into

the whole story of the Maya. Other studies of unusual interest are those on textiles of Guatemala, by Dr. Lila O'Neale, and on the origin of maize and its possible development in Middle America, by J. H. Kempton and Dr. Wilson Popenoe. Among questions of outstanding importance relative to the story of Maya civilization there are none ranking higher than the problem of maize, as there is reason to believe that upon this product, in some measure, the life and civilization of these people have been based. Study of the origin of maize, as it has been worked out in recent years, is one of the most significant efforts to reach back through the past to discover how features of importance in the present have been developed. It remains to be seen whether if such discoveries are made they can contribute to possibilities for the future, but it seems reasonable to assume that what man did in the earliest stages of his history might be duplicated in other ways in the future.

The investigations on anthropology and human geography by Dr. Morris Steggerda, of the Department of Genetics of Carnegie Institution, have been of unusual interest in fitting the program of the genetics-eugenics group of the Institution to the anthropological-historical studies necessary in attempting to obtain a knowledge of the present Maya of Middle America, and of the steps passed through in history of that group.

The investigation of Maya colonial documents and of the post-Columbian history of the Maya region presents another phase in the development of this story bringing recent stages, as recorded by documentary history, into touch with the past as made evident by records produced in a natural way at the time of the events.



## CARNEGIE INSTITUTION OF WASHINGTON

In the Section of the History of the United States, it is important to record bringing to a very significant culmination the work of Dr. Edmund C. Burnett in his monumental report on Letters of Members of the Continental Congress. During the past year, and within the period following his retirement from active service, Dr. Burnett has continued to the completion of his final volume and to the writing of a summary of results from these studies as seen through the mind of the investigator. Dr. Burnett has followed with painstaking care and fidelity the extraordinary record that members of the Continental Congress have left. Through the bringing together of these letters and giving us his interpretation he has made an outstanding historical contribution.

### RESEARCHES OF ASSOCIATES

No report of Institution investigations can be considered adequate without reference to the long series of studies conducted by the many research associates of this Institution located in many lands and examining problems in nearly the whole range of science. To touch these subjects in a report of this nature means, however, either a mere list or an outline so brief that it must be inadequate.

These researches are, moreover, treated fully in the Year Book report of the Institution along with the reports of Divisions and Departments, and it is hoped that they will be examined both with reference to their range, and to the results and conduct of the work.

In many cases the work of Research Associates is closely related to that of Departments and Divisions, thus giving stronger support to the special studies and help in the broader program of the Institution.

## PUBLIC RELATIONS AND PUBLICATIONS

Public relations of the Institution involve all contributions in the interest of the community, or which relate to application of knowledge obtained by the Institution to "the improvement of mankind." As a first responsibility we are concerned with making adequate record of results. We interpret as "adequate" such statements regarding new ideas, or the methods by which they have been secured, as will make possible the repeating of constructive or experimental work leading to significant result. While there is unquestioned advantage in having all conclusions of research published in a form which can be read and used widely, the first requisite is that the material be set down in a type of statement that can be followed by specialists interested either in application or in continuance of the work.

Other types of publication issued regularly by the Institution have included during recent years Supplementary Publications, releases, notices to the press, and a wide variety of materials giving notice of advances in research of the Institution in the course of the year.

In addition to the large number of special papers issued through scientific journals, or other commonly used channels, the Institution has published the following technical studies in the past year:

The eighth and final volume of "Letters of Members of the Continental Congress," by E. C. Burnett.

The fourth volume of "Judicial Cases concerning American Slavery and the Negro." Cases from the Courts of New England, the Middle States, and the District

CARNEGIE INSTITUTION OF WASHINGTON

of Columbia. Edited by the late Helen T. Catterall, with additions by James J. Hayden.

A volume of fourteen papers representing results of work at the Tortugas Marine Biological Laboratory of the Carnegie Institution on Loggerhead Key.

A volume of Contributions to American Archæology covering a considerable variety of subjects.

A volume on The Cenotes of Yucatan with eighteen papers assembled by A. S. Pearse.

Round Structures of Aboriginal Middle America, by H. E. D. Pollock.

Zacualpa: A Study of Ancient Quiche Artifacts, by S. K. Lothrop.

A volume on the Botany of the Maya Area.

Studies in Tree Growth by the Dendrographic Method, by D. T. MacDougal.

Hot Springs of the Yellowstone National Park, by E. T. Allen and Arthur L. Day.

East African Plateaus and Rift Valleys, by Bailey Willis.

The Physiology of the Elephant, by F. G. Benedict.

A series of Contributions to Palæontology, covering a wide range of problems on the Pacific Coast.

As in other years, the Institution has endeavored to present to the public through its series of regularly organized lectures, and through the annual exhibit, a careful statement of conclusions from certain of its major researches. In an agency of this type it is obviously not possible to absorb any large proportion of the time of the staff in preparation of lectures and exhibits. It has, however, been possible to present some of the outstanding results and to organize the lectures and exhibits on an

exceptionally high plane of quality and mode of presentation.

In furtherance of the effort of Mount Wilson Observatory to make available to the public some opportunity for appreciation of realities in the study of astronomy, the Trustees approved in the past year the building of an auditorium and exhibit room on Mount Wilson. This structure will give an excellent opportunity to hear discussion by members of the staff regarding some of the most important work of the Observatory. On Friday evening of each week visitors are also allowed brief opportunity to see objects of special interest through the 60-inch telescope. The exhibit room will contain the best illustrations which can be secured, covering photographic work of the Observatory on all types of objects from the sun and moon to some of the more important nebulae.

In connection with the opportunity of visitors to see some aspects of the work at Mount Wilson, effort is made to show something of the mechanism which the astronomer uses in conduct of his investigations. It is obviously not feasible to permit a large number of visitors to enter the buildings where the most careful researches are under way. But the interest of the public in these projects is large, and the Institution has attempted to meet it, so far as this may be done without diminishing effectiveness of the work for which the Observatory has been established.

### OBITUARY

For more than a quarter of a century Mr. George W. Wickersham, acting as Trustee of Carnegie Institution, was making important contribution to the advancement of science and research. Mr. Wickersham came to know the

Institution intimately through his twenty-six years of service on the Board of Trustees, functioning as a member of the Executive Committee for several years, as a member of the Auditing Committee for fifteen years, and, for twenty-one years, as a member and for a part of the time Chairman of the Finance Committee. In the Board of Trustees each member has a point of view representing at the same time an exceptional background of experience and special competence arising from his personal view of science as seen from the subjects with which he is especially familiar. Mr. Wickersham had a broad interest in all that touches science and education in their relation to human affairs and a mind trained to precision in thinking. These qualities made his comments of great value in the initiation and development of the major features of the Institution's program.

For those fields in which the activities of the Institution touched matters involving legal and financial questions, Mr. Wickersham always gave of the best that his knowledge and experience provided. It was also of great importance to the Institution that he was not merely interested, but was enthusiastic, concerning the constructive or creative program of the Institution. Although the precise lines of thought and exact definition of the contribution made through Mr. Wickersham's service on the Board would be difficult to formulate with exactness, it is of importance to make record in this report of the debt which the Institution owes by reason of his service, his thought, and his interest.

THE BUDGET FOR 1937

The budget proposed for 1937 has been constructed on the basis of estimates in which there is recognition of possible income changes due to future reinvestment at lower interest rates. Since the extent of such modifications can not be determined with exactness, the income has been estimated at low figures while the reserve for protection of income is made relatively high. In past years it has been possible to carry budget programs without financial loss, and without disturbance of research projects. In our plan of administration the safeguard of careful estimate on income and expenditure has been supplemented by the use of quarterly allotments, making possible the withholding from general expense of such sums as might be necessary in order to keep within limits of available income. Thus far in the history of the Institution, even during the most difficult periods in years of depression, no extraordinary measures for protection of the budget program have been found necessary.

Organized as the Institution is for the conduct of research and its use for benefit of the public, the source of income is found mainly in the interest upon securities. There is also a return from publications, corresponding, however, only to a small fraction of what is expended in issuing these contributions. Appropriations of varying amounts are also made by other agencies for conduct of special researches carried out by the Institution.

It is to be assumed that with development of the publication program papers and volumes representing the scientific record of researches will rarely return more than a small fraction of the original cost. Especially is this situation influenced by the fact that a large part of the

## CARNEGIE INSTITUTION OF WASHINGTON

Institution's publications are made available without cost to the greater libraries of the world concerned with research. Those publications which have to do with the more general statement of results intended for wide reading make a small return, and may ultimately bring a contribution of income approaching the original cost. With our effort looking toward continuing betterment of their quality the demand for these interpretative publications has increased considerably.

As in recent years, effort is made in this budget to hold the amount included in the Emergency Reserve at as high a figure as seems feasible. This fund has now grown to a sum which not only represents important opportunity for financing of emergency projects but is at the same time a definite protection to income and to capital.







## REPORTS ON INVESTIGATIONS



# DIVISION OF ANIMAL BIOLOGY<sup>1</sup>

GEORGE L. STREETER, CHAIRMAN

Under the Division of Animal Biology are included the various biological researches conducted by the Institution and primarily concerned with the physiology, anatomy, embryology, evolution and heredity of animals. As far as possible the various projects are located where they can be best conducted. The principal groups included in the Division are the Nutrition Laboratory located in Boston, the Department of Genetics comprising the Station for Experimental Evolution and Eugenics Record Office, both located at Cold Spring Harbor, the Department of Embryology in Baltimore and the Tortugas Marine Laboratory on Loggerhead Key, Florida. In the following report each group has supplied the account of its own activities for the year and the respective accounts should be read in their entirety, rather than placing any importance on the following summary, which is necessarily sketchy and incomplete. Anyone reading this summary and comparing it with summaries of other years, will, however, see to what a large extent these researches tend to overlap and bear one on another. In general the items will follow the sequence of the main body of the report.

Among the embryological investigations which have been made during the past year, those made on the study of the early stages of the macaque embryo may be ranked as of major importance. Fortunate in having adequate material, we have been able to start from the secure foundation of the free blastocyst and follow through a close series of stages the attachment of the egg to the uterine surface. The remarkable changes which then occur in both the egg and the maternal tissues, with which it comes in contact, are of great embryological interest. A wealth of new observations has thus been made, involving the problem of implantation on one hand and the segregation of the embryo-forming cells on the other. In terms of demonstrable structures we are now in position to reevaluate the conventional three-germ-layer doctrine. It has been possible to demonstrate, as the initial chapter in the development of the ovum, that the trophoblastic or auxiliary elements of the ovum are separated out and differentiated prior to the initiation of development in the embryonic or formative cells proper and that it is only among the latter that the three-germ-layer analysis can be applied. This will alleviate much of the controversy that has existed in the correlation of development in different animal forms, and removes the confusion due to the extreme specializations of the auxiliary membranes and implantation devices. Numerous other studies have been made on the development of different organs and body parts, notable among which is that on the yolk-sac. It will be seen in the reports that some studies have been made on the physiology of the embryo. The epinephrin content in the adrenal glands has been determined in chick embryos and experiments have been made which furnish the histological criteria by which tubular function of the kidneys can be determined morphologically in microscopic sections of human embryos.

<sup>1</sup> Address: Wolfe and Madison Streets, Baltimore, Maryland.

The structure and physiology of the cell (Cytology) is of course basic to embryology and therefore is a field to which our attention is always directed. Among such studies this report covers those on the chromosome which has been studied both from its structural and genetic standpoints. Germ cells, the cells of the hypophysis and cancer cells have been studied. In connection with the latter the notable discovery has been made that if tumor cells of one strain of mice are used to induce a foreign-protein sensitivity in another strain, the resistance of this other strain breaks down and tumors develop in some of the individuals. This makes it clear that there are at least two factors involved in the origin of a tumor: one, the permanently altered cell, and the other, the environment in which the cell must exist. In the experiments the unfavorable host-environment is altered so as to permit growth of the malignant cell.

Among studies on the physiology of reproduction, an important one is that of Dr. Markee and Dr. Hartman on the nature of menstruation. In their experiments they were able to transplant pieces of endometrium to situations where the phenomena of menstruation continues uninterrupted and at the same time the surface is visible for observations. The principal factor was found to be alterations in the blood-vessels involving vaso-constriction, stasis and vaso-dilation. Menstruation in the monkey was found to consist of multiple (estimated up to three thousand) minute hemorrhages spread over the course of four days. Individually they are very transient, all trace of the point of bleeding being lost thirty minutes after the hemorrhage occurs. Further studies have been made on ovulation, superfetation, and on pregnancy in the Chimpanzee.

In the field of the nervous system, the study of mechanisms of the frontal lobe which is being made by Dr. Hines and Dr. Tower is of extraordinary interest. They have shown that the pyramidal and extrapyramidal functions of the frontal lobe constitute a mechanism of greater complexity than had been supposed, and the mechanism is to be interpreted as facilitating and inhibiting activity at all levels of the cerebrospinal axis. It does this with the high degree of nicety which the effector system requires. Studies of the cerebrospinal fluid have been directed toward an investigation of some of the factors involved in its absorption. Experiments have been made demonstrating the splitting of the axones of the facial nerve and this explains the clinical phenomenon of facial tic which is seen after injuries of this nerve. The ganglion cells in the organ of hearing of cats have been studied in abnormal animals, the structure of the spinal cord of the finback whale has been investigated and also certain peculiarities of the floor of the third cerebral ventricle as seen in a variety of animals.

Anatomical studies which are herewith reported include observations on the comparative anatomy of shoulder and arm muscles, variations in vascular patterns in man and related primates, the vascular system of the whale, the thoracic and abdominal viscera of the orang-utan, and the nasal cartilages in large apes. Among studies of a more anthropological nature there are to be mentioned the observations which have been continued on the growth of children in different races. It has been found that height-weight charts, if they are to be used as a guide to normal development,

must be constructed separately for Navajo children and Dutch white children as compared with American children in general. Studies on the prevalence of dental caries among four races, varying in habits and kinds of food, indicate that heredity is a large factor in the occurrence of sound teeth. Studies of certain mental characteristics, comparing Indian and Negro with White children have been made, covering both ordinary activities and such functions as art appreciation. The study in variation of taste sensitivity in an average white population has been extended with more refined determinations and the thresholds for 14 substances have been obtained in 51 individuals. It is also being extended to other races, such as the Navajo Indians.

Investigations in plant genetics have been continued with selected species of *Datura*, in which chromosomal differences between species are analyzed through hybridization experiments. These studies include the correlation, for the various races which compose each species, of the chromosomal peculiarities with the specialization of anatomy and physiology of the respective plants. Also they extend to the probable internal structure of the chromosomes involving the study of the differences between species in respect to the genes. By the action of x-rays and radium upon the chromosomes, coupled with hybridization methods, success has been had in producing a new pure-breeding type in which an excess of material within the chromosomes is correlated with changes in the appearance in the plant. The new type seems to be brought about by the addition of blocks of genes and thus involves multiple characters in the plant. Studies on the increased mutation rate by the aging of seeds and injury to them by heat and moisture has been extended to similar treatments of pollen. It has been found that the mutation rate is higher following pollen treatment than seed treatment. When treated pollen was used, mutation was seen in 15 per cent of the 300 plants tested.

Studies of the gene have been continued, and chromosome deficiencies identified by genetic methods are being correlated with visible changes in the large chromosomes of the salivary glands in *Drosophila*. A matter of especial interest is the discovery that the natural mutability of the wild Florida inbred stocks of *Drosophila melanogaster* is much higher than any heretofore studied. Experiments with these stocks indicate that the factor responsible for the increased mutability is nuclear, and is located in the autosomes, and is probably a single gene. Furthermore its affect on other genes is not limited to any single one, though it affects some more readily than others.

Other studies dealing with the structure of chromosomes have been successfully carried out. It has become clear that the giant chromosomes found in the epithelium of the salivary gland are formed in some other way than as an aggregation or multiple bundle of linear units. Further details have been learned regarding the chemico-physical nature of the transverse bands which are so conspicuous in these chromosomes, and this constitutes a step toward the delimitation of the physical foundation of the gene concept. The factors involved in chromosome movements have been reviewed and the conclusion is arrived at that the essential mechanism is initiated

by several agencies, any one of which can bring about the necessary chromosome movements where, due to the widely varying conditions prevailing in plants and animals, the others can not act.

A correlation between tissue metabolism and microscopic changes of the cells has been found to have significance in the early diagnosis of leukemia in mice. Before leukemia can otherwise be recognized, it is found that the metabolism of the lymph nodes rises and this is accompanied by abnormal transformations of the reticular cells. A few weeks later, following a continuous rise in metabolism, fully developed leukemia sets in. Thus the abnormal reticular cell transformations have been found to be the initial cellular manifestation of this disease. Furthermore direct evidence has been obtained on the nature of the injurious effect of leukemic cells, in that it is found that these malignant cells exert a depressing effect on the metabolism of normal tissue, a lowered anaerotic glycolysis of the peripheral lymph nodes. Other malignant growths appear to have a similar effect. Other studies in mouse-leukemia include investigations on induced resistance, and comparison of the resistance following repeated small doses of leukemic cells and that following embryo tissue treatment. The latter is found to be more temporary. In some cases of leukemia there develop lymphosarcomata which appear to be transformations of leukemic cells. The demonstration of this relationship is of great importance to those concerned in the origin and control of malignant tumors.

In the studies on endocrinology, further observations have been made on the nature and functions of prolactin. It has become apparent that, including its primary and secondary effects, prolactin involves more than the phenomenon of lacto-genesis. Its complicated constitution is shown by the fact that nine different responses are already known to be called forth by its use. It is concluded that the hormones of the anterior lobe of the hypophysis are not numerous, probably only three or four, but they are very versatile, and their analysis requires the careful attention of experienced investigators, provided with the best facilities. One of the ways being utilized to solve this problem is the study of the effects of removal of the hypophysis in pigeons. Also by correlating the cytological manifestations of the hypophyseal cells with the different stages of the reproductive cycle and where the endocrine glands have been experimentally altered by appropriate hormone administration, it has been found that the basophile and acidophile cells show definite changes in functional state, depending on their respective secretory state.

A study has been made of abnormal sexuality in pigeons with hereditary bearings. Observations have been continued on the basal metabolism of birds under different physiological conditions and it is now possible to state that the critical temperature for both thyroidectomized and hypophysectomized pigeons is 25° to 27° C., which is three to five degrees below that prevailing for normal pigeons. It was found that the follicle-stimulating hormone, when used alone, has no effect on the basal metabolic rate. Thyreotropic hormone and prolactin, however, do increase metabolism and particularly when working together. Other hormonal studies have been made

in the Department of Embryology, including activity of hypophyseal tissue grown in cultures and studies of the hypophysis of *Selachia*.

At the Eugenics Record Office further progress has been made in the determination of the rules in the thoroughbred running horse by which racing capacity can be predicted of offspring of parents of a known capacity. There have now been completed ten kinship analyses, each based on the measured racing capacities in at least 1000 foals. These kinships include grandparents, parents, fraternal and  $F_1$  offspring. Studies have been continued on methods of obtaining a more definite measure of consanguinity as an aid to a more systematic analysis of the pedigrees of human qualities indexed in the files of the Eugenics Record Office. A reliable measure of this kind will be of value in the study of the thoroughbred horse data as well as for genetic analysis in general. Other studies in the Eugenics Record Office include the completion of the Pan American Master Map, with a standard grid which enables one to compare accurately any one Pan American area with another. This work was done in collaboration with United States Coast and Geodetic Survey and should be of value for the purpose of indexing data and computing resemblances in various types of historical and geographic researches. Related to this work is a study that is being made leading to the codification and analysis of the immigration laws and policies of the 41 primary political subdivisions of Pan America.

Because of the meticulous care and ultra-refinement of the technique under which basal metabolism studies have been conducted at the Nutrition Laboratory and because of the unique standards, which have been established under such favorable circumstances, the laboratory has found itself associated with a wide variety of cooperative endeavors where detailed reliability is essential. The researches for the year thus cover several fields of investigation and involve a number of non-resident workers. The unusually profitable cooperative research with Professor Ritzman has continued and further observations have been made on large domestic animals. Various factors that determine basal metabolism have been studied, such as season, lactation, sex and the constitution or type of the individual animal. In cooperation with Dr. Bensley of the Montreal General Hospital important observations have been made on heat elimination of the human subject after the ingestion of sugars, with results compared as obtained by direct and indirect calorimetry. The study was extended to include respiratory exchange, alveolar air and blood-lactic acid after such ingestion. In cooperation with Dr. Root and Dr. White a study has been made of the prevention of respiratory failure by the use of a helium oxygen mixture. A similar study has been made with Dr. Barach for the relief of dyspnea. Studies have continued jointly with the Department of Embryology on metabolism in the macaque monkey. The work with Professor Sherman on old age in rats has been completed. Cooperating with workers in foreign countries, metabolism observations have been obtained for natives in Hawaii, Samoa and China. Other metabolism studies include those on different races of the rabbit, different races of mice, thyroidectomized geese, and the woodchuck. Additional physiological observations have been made on the



elephant, covering such features as skin temperature, heart and respiration rate, sleeping habits, feeding requirements and efficiency of the digestive system. It may be added that as another instance in which it has absolved its obligation to public interests, the Nutrition Laboratory has devised a new inexpensive pipe-stack form of basal metabolism apparatus which is suitable for humans and can be operated for student instruction and in clinics.

During the twelve weeks of its operation, the marine laboratory at Tortugas was visited for longer or shorter periods by sixteen investigators. Because of the unusual facilities in the study of marine animal life prevailing there, investigators assemble from widely separated parts of the country, each to carry on his particular research. The studies carried on during the past summer include observations on the taxonomy of fishes; embryological studies on turtles, sharks, and sponges, motion picture studies of tissue cultures of cells from cæcal pouches of *Ptychodera*; metamorphosis and its acceleration in *Ascidia*; regeneration in *Crustacea*, *Holothuria*, *Perophora* and *Ecteinascidia*; excretion of creatine by fishes; relationships of the blood serums of various crustacea and mollusks; experiments in irradiation of eggs in various dyes; photoelectric effects in *Valonia*; and other physico-chemical studies of marine animals.

DEPARTMENT OF EMBRYOLOGY <sup>1</sup>

GEORGE L. STREETER, DIRECTOR

## EARLY EMBRYOLOGICAL STAGES

A major interest among the members of this department during the past year has been the study of the early stages of the macaque embryo, for which we are fortunate in having adequate material. Starting from the secure foundation of the free blastocyst, we have a close series of stages in which one can follow the attachment of the egg to the uterine surface. The profound changes which then occur in both the egg and the contiguous maternal tissue are of great embryological interest. Although having the material directly under our eye it has been necessary to carefully analyze all the factors concerned and, as is required in all complex biological phenomena, to be somewhat guarded in our conclusions. We find ourselves safe to the extent to which we limit our attention to cell structure and tissue alteration that can be seen and photographed. A wealth of new observations based on this type of fact is being put in form as rapidly as possible. At the same time an effort is being made to integrate the phenomena seen in this primate material with corresponding phenomena in lower forms.

## THE THREE-GERM-LAYER THEORY

Because of the difficulties met with in fitting our observations made on early macaque embryos into the conventional three-germ-layer theory it has been necessary to reevaluate in terms of demonstrable structures the implications of that distinguished but diagrammatic doctrine.

It is found in the macaque that prior to the laying-down of the so-called three-germ layers an earlier, and thus more primordial, mechanism has already taken place, namely, the materials which are to form the envelopes and devices for implantation of the embryo have been segregated from the material which are to form the embryo itself. That is, the developing ovum, as Hubrecht maintained, is composed on the one hand of "formative substances," in the sense of forming the embryo, and on the other hand of what I would call the "auxiliary substances" which play but a temporary rôle and are discarded at birth. Segregation of the latter "auxiliary substances" occurs simultaneously with and perhaps is the chief result of cleavage. The precocious differentiation into a trophoblastic shell is found to constitute a fundamental and initial chapter in development which occurs long before there is any possibility of speaking of three-germ layers.

It is found that already on the ninth day the auxiliary structures of the macaque ovum are set apart from those cells which are to form the embryo, and that the two groups can be traced as permanently separate systems, cooperating and abutting, but never changing one into the other.

As for the use of the three-germ-layer terminology, it is the conclusion of the writer of this report that, if we are not to distort observable structures, it should be restricted, as a relatively late phenomenon to the embryo

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proper. It can not be satisfactorily extended to the auxiliary parts of the ovum, which are modified in many ways in adaptation to the specialization of the reproductive tracts of the animals concerned.

#### IMPLANTATION OF THE MACAQUE OVUM

The mechanism by which the primate egg becomes implanted in the lining membrane of the uterus has been studied by the writer in collaboration with Dr. G. B. Wislocki of the Harvard Medical School. A preliminary account was presented before the American Association of Anatomists.

It is found by these investigators that the egg is free until the ninth day. At that time the trophoblast cells at the embryonic pole of the blastocyst undergo active proliferation and the more superficial ones take on the character of syncytium and make the first attachments. Up to then the endometrium shows little change. Beginning with the tenth day the endometrial epithelium proliferates and forms a sharply localized plaque which the ovum erodes so as to abut on the underlying stroma. On the eleventh day a similar and equally large plaque appears on the opposite wall, constituting the secondary implantation site. This occurs before there is any attachment of the ab-embryonic pole of the egg.

The plaque stage persists until the chorionic villi are formed, about the sixteenth day, and then the margin, separating the embryonic structures from the maternal, takes the form of an advancing zone of degenerating tissue, which we interpret as corresponding to the fibrinoid stripe seen in human material. This peripheral degenerating crust maintains a rather uniform thickness in the subsequent stages and can be recognized in the fully formed placenta. We can thus speak of a plaque or previllous stage of implantation as distinct from the fully developed type which succeeds it. A complete presentation of this material is now in preparation and is to be included in a volume of the Contributions to Embryology devoted to the studies on the macaque embryo.

#### BORDER ZONE IN THE PRESOMITE HUMAN EMBRYO

Basing her study primarily on the "Yale" ovum, which approximates the stage of the Peters ovum, Dr. E. M. Ramsey has concluded that the periphery of the ovum, or trophoblast, exhibits a more active and advanced development in the basal portion than on the opposite (superficial) side of the ovum, in other words the placental pole is indicated at this early stage. Dr. Ramsey has studied the remarkable changes which occur in the maternal vascular system in the neighborhood of the ovum, in which we are only beginning to recognize the range of normal alterations as distinguished from the pathological. Another phenomenon of interest is the reaction which she has found to occur wherever the embryonic syncytium invades or comes in contact with the maternal stroma. It is usually marked with necrosis, hemorrhage and edema, all of which we ordinarily think of as pathological processes. This study is preliminary to a full account of this embryo, which because of its importance has been presented to the Carnegie Collection.

### ORGANOGENESIS

During the past year a number of developmental studies have been made of different organs and body parts, accounts of which are complete and in the process of publication. But since it is our rule as far as possible to limit this report to published work, a description of these particular studies will be deferred to next year. Included among them are Dr. J. D. Boyd's study of the development of the carotid body in the human embryo, Dr. H. W. Mossman's review of the morphogenesis of the fetal membranes of various mammals, Dr. E. M. Ramsey's study of the Lockyer embryo, Dr. E. H. Norris's study of the development of the parathyroid and lateral thyroid glands, Dr. A. H. Schultz's study of fetal growth in the macaque, and the investigation of Dr. L. B. Flexner and Dr. I. Gersh on the function and structure of the metanephros in pig embryos correlated to oxygen consumption.

#### ORIGIN OF THE YOLK-SAC

Taking advantage of the favorable opportunity offered by our macaque embryos for histogenetic studies, Dr. C. H. Heuser has directed his attention to the yolk-sac whose origin is closely interwoven with that of the primary lining membrane of the blastocyst or the coelomic membrane and also designated as the "Heuser membrane."

The undifferentiated cells which are destined to form the coelomic membrane are traced back to the 9-day blastocyst whose 370 constituent cells fall into three categories: 314 of them are clearly trophoblastic; 32 of them are formative cells from which the embryo is derived; and 24 are set off or delaminated from the ventral surface of the formative cell-mass somewhat as the trophoblast cells become segregated from its dorsal and lateral margins. From these 24 undifferentiated cells one can trace not only the formation of the coelomic membrane, but also a part of the yolk-sac. The coelomic membrane was found by Dr. Heuser to be complete on the twelfth day, and it is not certain but that to the original cells some are added as subsequent delaminations from the trophoblastic wall.

On the twelfth day one can first recognize the yolk-sac, a little smaller and closely applied to the ventral surface of the germ-disk. It at first is slit-like or lens-shaped with embryonic (dorsal) and ab-embryonic (ventral) walls, and these two are from the outset quite different in appearance and sharply marked off from each other; the dorsal part or wall is a layer two or more cells thick, whereas the ventral part of the yolk-sac is composed of flattened cells constituting a thin membrane, which shows on its outer surface occasional strands still connecting it with the coelomic membrane. The striking duality shown by the yolk-sac in its earliest stages is a phenomenon which was wholly unexpected when these studies were started.

#### DEVELOPMENT OF THE BLOOD-CELLS IN THE MAMMALIAN FETUS

Studying the pig, rabbit, rat, dog, cat and man, Dr. M. M. Wintrobe and Dr. H. B. Shumacker of the Department of Medicine of the Johns Hopkins University have made observations on the number of red cells,

the amount of hemoglobin present and the volume of packed red cells at various fetal and new-born stages. From the data they have derived the average volume, diameter and hemoglobin content of the single cell during the process of development, and they have also determined the proportion of immature red cells present. This comparative data is important to the hematologist and had heretofore been lacking. The complete data were too voluminous for publication but have been deposited in the archives of our laboratory where they are available for examination to other investigators.

Dr. Wintrobe and Dr. Shumacker have found that the red cell count, hemoglobin and volume of packed red cells are at first very low as compared with those of adults of the same species. On the other hand, the red corpuscles are very large, chiefly nucleated, and contain correspondingly high amounts of hemoglobin. As the fetus develops, the number of red cells, hemoglobin and mass volume increase, whereas, the mean size of the cells, the quantity of hemoglobin contained in them and the proportion of immature red cells decrease. The relation of hemoglobin to the volume of the corpuscle tends, however, to remain constant, and this is what we would expect if hemoglobin bearing is to be the sole function of the red cell.

There is a period in man and the rabbit in which blood formation is very intense in the liver. It is during this period that the above changes take place most rapidly. It is of interest to know that the number and size of the red corpuscles and the proportion of immature red cells at birth tend to be more nearly the same as those of adults in species which have longer gestation periods. In other words birth is not closely correlated with the progress of red cell differentiation.

#### RECAPITULATION IN THE RED BLOOD-CELL

In a study of the red blood-cell from the comparative embryological standpoint, Dr. G. W. D. Hamlett has shown the danger of erroneous interpretation as to the recapitulation in development. He shows that in the opossum embryo, differing from placental mammals, there is a short interval (10 to 17 mm. embryos) when the nucleated red cells resemble the fusiform reptilian red cell. But this stage is entirely absent in other mammals. The preceding nonfusiform nucleated stages therefore can not be properly designated as reptilian. It is safer, in Dr. Hamlett's opinion, to regard them as embryonic stages with no commitment as to their "ichthyoid" and "sauroid" resemblances. Dr. Hamlett's observations have been presented in preliminary form. His paper with photographs is now being assembled for final publication.

#### PRIMORDIUM OF THE HAND AND FOOT SKELETON

As an aid to the comparative embryological investigations of Dr. H. Steiner in Professor Heschelar's laboratory in Zurich we supplied a series of Caiman embryos which we had collected through the cooperation of Professor A. M. Reese. Using this material Dr. Steiner has made an important contribution to the embryology of the hand and foot skeleton of this reptilian form. In these embryonic stages he finds clear evidence of the close relationships which exist between the birds and this persisting type

of ancient reptile and thus we are able to conjecture the form of the earliest tetrapod extremity.

#### INHERITANCE IN PARAMECIUM

In the report of last year the interesting experiments of Dr. C. F. DeGaris in which, after producing double monsters in *Paramecium*, he was able by this characteristic to identify them as they conjugate with free individuals. He could identify or tag a given line and follow it as it is crossed with another, being sure of the crossing and isolation of known materials.

His experiments in producing crosses between pure lines of *paramecia* began in 1928 and were continued several years. A review of all this work has recently been prepared by Dr. DeGaris, with a complete account of his experiments from the outset. His work demonstrates that conjugation of a double monster with free individuals, whether by one or both components, can give rise to durable lines, and this is true whether the free individuals are of the same or a different pure line. He finds that conjugation frequently lowers the vitality of the conjugants, so much so as to prevent their vegetative reproduction. In the specimens where one member of a mating is lowered, the vitality of the other member also tends to be lowered to about the same extent. He further finds that conjugation gives rise to lines which exhibit diversity from the parent stocks but, without exception, similarity of the progeny. In other words conjugation in this experimental material results in biparental inheritance and the production of heritably diverse races. It is also of significance that where only one component of a monster conjugates with a free mate, the other component also produces progeny and these retain the characteristics of their own line. This proves that the cytoplasm of the non-conjugant part of the monster is not altered in its genetic constitution by foreign conjugation of the other component, though the cytoplasm of the two are continuous.

#### CYTOLOGICAL STUDIES

##### CHROMOSOMES

Working with Dr. Metz, Dr. C. A. Berger has studied the multiple chromosome complexes found in the midgut of the mosquito. It had been suggested that, on the basis of the manner of multiplication of these epithelial cells, evidence is provided of the compound nature of the salivary gland chromosomes. The pupal intestinal epithelium was reported to have multiple complexes of 12, 24 and 48 chromosomes, the diploid number being 6. It was also reported that the large cells of the larval midgut had nuclei and chromosomes resembling the salivary gland type. Putting these together it was argued that these huge intestinal chromosomes of the mosquito give rise to the multiple complexes found in the pupal intestine, by simply separating into their component units, and this of course would speak for the essentially compound nature of the salivary chromosomes which they so closely resemble. In attempting to verify this matter Dr. Berger has confirmed the presence in the larval midgut of large epithelial cells with chromosomes consisting of thick chromatic cords visible in the resting nucleus and closely similar to the salivary gland chromosomes. But

no evidence was found that these large cells ever divided. Instead, their number was supplemented during larval life by the growth of small regenerative cells which seem to be present from the time of hatching. In the meantime the large cells are shed into the lumen and disintegrate without division. Furthermore Dr. Berger found that the multiple chromosome complexes are found in the more anterior part of the intestine (ileum) in epithelial cells which are actively proliferating between the twelfth and eighteenth hours of pupal life, preceding which time, throughout the larval period and the first hours of pupal life, the nuclei of these cells are in the resting stage and in no ways resemble the salivary gland type of nucleus. Thus if we are to prove that the large salivary gland chromosomes are compound in nature it must be done in some other manner than the above.

How the giant chromosomes found in the salivary gland of *Sciara* attain their huge size presents an obvious problem. Along with their respective nuclei and the epithelial cells which contain them, they grow to thousands of times their original size without the occurrence of cell division. It has been held by some that this is accomplished by an internal multiplication of parts. This would seem necessary if there is a fixed limit to the size of the component elements. The size of the chromosome would then depend simply on the amount of multiplication of its basic elements. In a report to the American Association of Anatomists, Dr. C. W. Metz presented evidence that such an hypothesis can not be substantiated and that the giant chromosomes can not be regarded as multiple with any more justification than can the cells themselves.

Evidence that the large salivary gland chromosomes can not be explained simply as a composite bundle of chromosomal units has been obtained by Dr. Metz and his coworkers from several approaches. Working jointly with Dr. W. L. Doyle he has made a cytological study of the gland nuclei in *Sciara*, comparing their structure as seen in living tissue with their appearance on treatment with various coagulant fixatives; acetic acid, formalin, osmic acid, mercuric chloride and various concentrations of salt solutions. First of all, they found that in isotonic salt solution, and under conditions as near normal as possible, the nuclei show no indication of chromosomes. Instead, the nuclear membrane incloses a homogeneous fluid containing several granular streaks or masses. On further study it was found that this scanty granular material is arranged in thin layers which partially outline convoluted transparent cylinders, *i.e.* chromosomes, the two completely filling the nucleus, there being no visible extrachromosomal nuclear fluid.

Then proceeding on the basis that the chromosome consists of a delicately poised colloidal gel of complex constitution, they employed various experimental fluids and demonstrated that variations in osmotic pressure acidity and specific ions produce various characteristic patterns, which appearances are therefore artifacts. Almost all solutions employed caused a loss of water from the chromosome, leaving aggregations or precipitations of the dispersed phase as a matrix or reticulum which is apparently a protein. The size of the spaces in the reticular mesh was found to be dependent on the nature of the coagulant employed and the manner in which it was used.

As for the chromatic bands or segments, their appearance or disappearance was found to be dependent on the changes in indices of refraction as the chromatic and achromatic portions are variously hydrated and dehydrated; that is, it is not a matter of a separation and fusion of the chromatic segments. On the contrary the chromatic discs seem to be always present as specific differentiated structures, though they are not always visible. Thus the size of the chromosomes must depend on something other than an aggregation or multiple bundle of linear units.

The honeycomb or alveolar network in the achromatic material of chromosomes which has been demonstrated as a product of coagulation by Dr. Metz is the explanation given by him for the longitudinal threads or chromonemata described by other investigators. He finds them absent in relaxed chromosomes but present as lines of stress when the material is stretched or twisted. The appearance of threads seems to be due in part to the formation of ridges on the surface and in part to distortion of the internal honeycomb network. In these studies Dr. Metz has improved the photographic technique for recording the finer cytological details, and by focusing at different levels a more accurate determination of the structure has been obtained than could be had by direct observation alone. By this means he has been able to demonstrate that the bands traversing the chromosomes are in reality discs and not rings.

With respect to the chromatic granules which had been described as being constant in number for each level, Dr. Metz finds that they may differ in number in different bands and that they vary with the fixative used. Their supposed constancy is explained by him as the result of stress lines and surface ridges which tend to align smaller granules with larger ones. In these studies it is evident that one can not be too particular in verifying the structural nature of the objects before attaching to them far-reaching conclusions.

#### FACTORS INFLUENCING CHROMOSOME MOVEMENTS

New aspects of the problem of the cause of chromosome movements have been brought to light by Dr. C. W. Metz. From study of his *Sciara* material he concludes that mitotic movements involve complex processes and that chromosomes take an active rather than passive part in them. He points out that there is a structure in the chromosome where the spindle fiber is inserted ("insertion body") which is morphologically distinguishable and which probably serves as an organ of propulsion. Its activity is apparently correlated with that of other agents.

Another source of activity is found to be a material distributed throughout the entire chromosome and is not localized in the insertion body. It is probably non-genic and is probably matrix-sheath substance. Dr. Metz conceives that it may alter the viscosity of the protoplasm in front of and behind the moving chromosome.

Other forces such as electromagnetic forces can not yet be discarded. Furthermore it seems probable that forces may be operative in some organisms which are not present in others. Plant cells may be different from animal cells. But such a fundamental process, so uniform in plants



and animals, makes it probable that the essential mechanism is capable of operation under widely varying conditions and it is not likely that it is dependent on a single agency. Dr. Metz presumes a multiple insurance whereby there are several agencies any one of which could bring about the necessary chromosome movements should the others fail to act.

#### CULTURE OF EMBRYONAL GERM-CELLS

Because of their biological preeminence among the body-cells, great interest is attached to the origin and structure of the definitive germ-cells. Dr. G. Muratori, University of Padua, as guest in our laboratory, has utilized the technique of tissue culture for the study of these cells in the living condition. He succeeded in obtaining them (germ-cells of chick embryos) in culture suitable for observation at various stages of development. An account describing their cytological characteristics and behavior has been prepared by him for the Contributions to Embryology (volume 26) and has also been published in an Italian journal. His observations on the changes in the physico-chemical properties of the cytoplasm are of special interest. He was able to demonstrate alterations in surface tension of the germ-cells along with softening of the ectoplasm which were expressed in ameboid activity, extrusion of pseudopodia and changes in cell form. However, no relation was detected between these pseudopodia and the migration of the cells. During marked ameboid activity no cellular displacements were observed. In the cultures the germ-cells migrated either alone or in groups and characteristically in cords. Very commonly they are seen as multinucleated masses without discernible cell boundaries. Dr. Muratori found that in the differentiation of the cells, the nuclei showed special characteristics for the different steps in the process. He divides the process into four stages: the undifferentiated gonad; the ovarian cortex of 10 to 14 days; the same at 15 days; and the same at 16 days and baby chicks, at which time there are well-defined chromatin filaments which already may be fragmented.

#### CYTOLOGY OF THE HYPOPHYSIS

The great importance that is now attributed to the activities of the hypophysis has led in recent years to renewed study of the structure of this obscure gland and to the search for microscopic evidences of its secretory products. Certain homogeneous masses seen in stained preparations in the spaces of its posterior lobe and known as the "hyaline bodies of Herring" have been suspected, among other things, of being the sought-for hormones or at least their precursor. During the past year Dr. I. Gersh and Mr. A. D. Tarr have subjected these hyaline masses to various tests and have proven them to be artifacts and have demonstrated that they are not the precursors of the important "pressor" and "oxytocic" substances which the pharmacologist extracts from the posterior lobe.

Dr. Gersh and his coworker took advantage of the freezing and drying technique by which the relatively slower separation of solid from liquid occurring with the usual fixations is avoided. Using the hypophysis of various animals (dog, cat, macaque, guinea-pig, ox, pig and chicken) they

found that when the fresh tissue is promptly frozen in liquid air and then dried in a very low vacuum and subsequently sectioned and stained, no hyaline bodies of Herring occur. Instead, the neuroglial tissue is infiltrated with a homogeneous stainable material, in which there had been no opportunity for the solid phase of the solution to separate out from the liquid phase. The hyaline bodies of Herring occur only when the latter separation takes place, as always happens during fixation, and are therefore artifacts.

Extending their studies, these investigators demonstrated that the protein solution which is homogeneously distributed throughout the meshes of the neuroglia and from which the hyaline bodies can be artificially derived has properties of extraction similar to an albumin. Moreover, this extractable protein can be separated from the pressor-activity principle, and there is no evidence that it or the hyaline bodies derived from it are the immediate source of the pressor principle. Thus we find that the hyaline bodies can be numerous in the posterior lobe of the dog and almost absent in that of the beef, while the gland extracts of these two forms show in proportion to weight the same pressor and oxytocic activity. In the further search for the hormonal substances originating in the hypophysis, the endocrinologist need not be misguided by these hyaline bodies of Herring.

#### SELACHIAN PITUITARIES IN TISSUE CULTURE

In previous investigations Mrs. M. R. Lewis has studied the pituitary body of the dogfish and skate in tissue cultures. During the past summer the work was continued and the different lobes of the gland were studied separately and in improved media. The epithelium of the pars intermedia was found to grow more slowly than that of the pars distalis and pars medialis. The cells of the pars neuralis also have their characteristic growth. The saccus vasculosus in many instances failed to grow even in autoplasm. These pituitary growths continued in good condition up to two weeks, and the cells of the different tissues retained their characteristic granules. It was found that extracts from the growths of the pars distalis and the pars intermedia brought about the darkening of sun-bleached frogs, proving that the melanophore-expanding substance in such cultures remains active. This opens another method of approach to the study of the melanophore phenomenon.

#### PINOCYTOSIS

New motion-picture films have been made by Dr. W. H. Lewis showing further details of the phenomenon of pinocytosis by which cells engulf droplets of fluid through the activity of their thin ruffle-like pseudopodia. His earlier observations were described in Year Book No. 30 and related particularly to macrophages. In the studies of the past year the same process has been followed in malignant cells from sarcomas and carcinomas. Thus far we are in the dark as to the stimulus which initiates the process and the physical factors by which it is accomplished.

#### ABNORMAL CELL DEVELOPMENT AND CANCER STUDIES

In previous reports reference has been made to the studies of Dr. W. H. Lewis and how these have led to his conclusion that the malignant cell is

a permanently altered one that breeds true. After such malignant cells are once established they multiply independent of the environment or agent which produced them and the growths can be continued indefinitely by transplantation from animal to animal and by means of tissue cultures. Although Dr. Lewis found that chromosome irregularities are very common in malignant cells, he has regarded these irregularities as secondary to the alterations in the other parts of the cell, such as the cytoplasm and centrosomal system. The latter characteristics show great constancy while the chromosomal number and behavior are subject to considerable variation, and would therefore appear to be a secondary rather than primary phenomenon.

The relation of abnormal mitosis to malignancy has been studied further by Dr. W. Mendelsohn. He has studied tumors (sarcomata) which arise in the walls of *Cysticercus* cysts in livers of rats which have been fed eggs of this parasite. The material was studied in tissue cultures which offer special advantages for chromosome observation. The developing *Cysticercus* larva induces an inflammatory reaction in which the liver cells when cultured exhibit many atypical mitoses, particularly multipolar types and also examples of lagging and aberrant chromosomes, and asymmetrical divisions. Dr. Mendelsohn found that similar abnormalities do not occur in other types of inflammatory reaction. For comparison he injected mustard in rat livers and studied the resultant proliferative reaction and found no tripolar or atypical mitoses. Thus the *Cysticercus* reaction is specific and its accompaniment with abnormal chromosomal behavior in the early stages, before the sarcomata have appeared, is evidence that the carcinogenic agent is already at work. The malignancy which follows in the cyst walls is therefore at least associated with atypical mitosis. It is also to be added that the more cysts present, and so the more active the cell division, the more rapidly and certainly do the sarcomata appear. So we can not yet discard chromosome behavior as part of the cancer problem.

After extended observations and experiences with the explantation of a large number of human and animal tumors, and the maintenance of continuous culture of many of them, Dr. G. O. Gey and Mrs. M. K. Gey have come to a conclusion similar to that of Dr. Lewis, which was outlined in my last report. They find that tumor cells are mutant cells with specific fixed characteristics which are retained in cultures for long periods of time and probably indefinitely. Even those which closely resemble normal cells, exhibit a difference in cultural behavior when carefully compared.

As experience with cultures of normal and malignant tissues accumulates it has been found desirable to maintain pure strains of cells in continuous culture. Because of their uniformity in appearance and behavior, such cells constitute an available source of uniform biological material, in somewhat the same way that pure strains of animals are essential to the geneticist. Such strains provide a base-line for many kinds of experimental procedures. In this direction Dr. and Mrs. Gey have accumulated a large experience and have amplified and refined the necessary technique to a high state of perfection and have shown that human tissue cultures can be

maintained in continuous cultivation with no greater difficulties than are met with in animal tumors. With their improved methods they now have a human tumor which has been cultured four and one-half years since the culture was started, and for a similar period of time a rat sarcoma. Strains of cells from both of these tumors are still under cultivation.

Because of its importance to other workers, Dr. and Mrs. Gey have published a report of their various experiences and new techniques in the management of tissues and preparation of culture media suitable for the purposes of continuous culture. They have opened the way whereby, with fairly simple means and without a great amount of labor, relatively large quantities of human and animal malignant and normal cells can be maintained for controls and for various experimental purposes. It is of interest to the biologist to know that the same end-results may be obtained by very different methods and media. Though the minute environmental conditions under this highly artificial manner of existence is of great importance, the cells nevertheless seem to participate in the control of their own destiny.

It has been found by Mrs. M. R. Lewis that certain cancer-producing hydrocarbons (dibenzanthracene, benzpyrene and methylcholanthrene), when added to cultures of embryonic tissues lead to photosensitivity of the cells, to the extent that the electric light ordinarily used for the study of the cells causes changes in the cytoplasm and nucleus and inhibition of cell division. Following this among the survivors there occur abnormalities of mitosis such as mark malignant growths, and as was seen in *Cysticercus* tumors by Dr. Mendelsohn.

Various methods of adding the hydrocarbons were tried and the most satisfactory procedure was found to be the use of a hanging-drop culture which had been allowed to grow for twenty-four hours in a nutrient saline medium, which medium was then replaced by a suspension of one of the hydrocarbons in chicken plasma. After one or two days the culture is ready for exposure to light. It was found that when too small amounts (less than 0.05 per cent) of hydrocarbons were present or when the cells were too far away from the hydrocarbon particles, they behaved normally in the bright light. If, however, there was 0.05 to 0.1 per cent of the hydrocarbon in the culture medium, the cells remained undamaged and division proceeded normally so long as they were under dull light, but when exposed to bright light the cells began to change in appearance and cell division ceased within two to ten minutes. We thus have a condition related to the studies of the photodynamic action of fluorescent dyes reported last year and it is to be noted that the hydrocarbons used in this year's experiments are fluorescent.

In the present experiments Mrs. Lewis found that after exposure both to the hydrocarbon and bright light the cytoplasm of the cells became more fluid and the increase in fluidity continued during cell division. In the resting cells the condition of the nucleolus, the nucleus, and the nuclear membrane resembled that which follows exposure to acid. Among the cells which recovered from the photodynamic action, cell division was resumed, but various abnormal features marked the chromosomal behavior. Experiments have been undertaken to determine the nature of these phenomena,

but thus far the factors which lead to photosensitivity of the cells and the part played in it by the hydrocarbons are unknown.

#### BREAKING-DOWN OF RESISTANCE OF MICE TO TRANSPLANTED TUMORS

Mrs. M. R. Lewis has found that if tumor cells of one strain of mice are used to bring about a foreign-protein sensitivity in another strain, the resistance of this other strain breaks down and tumors develop in some of the individuals. Previous experience had shown that a tumor arising in a mouse of any pure inbred strain can be transplanted into mice of the same strain but not into mice of a different strain. The resistance of mice of one strain to tumors transplanted from another strain was generally recognized and was regarded as one of the signs of the purity of the strain. When Mrs. Lewis discovered that this resistance could be broken down, she undertook, with the experienced assistance of Mrs. Edna Golden Lichtenstein, a series of experiments to determine the range within which this could occur.

It was first shown by them that tumor cells from "A" strain mice, if introduced every five days into "BA" strain mice until they had thirteen inoculations, would produce tumors after the sixth inoculation. The first six inoculations did not produce tumors but they produced a change in the mice inoculated. Of 24 "BA" strain mice thus inoculated with "A" strain tumor cells, 19 eventually developed tumors.

In carrying the experiments further, tumor cells from "BA" strain mice were inoculated in "C<sub>3</sub>H" strain mice. After several inoculations, some of the implanted pieces began to grow. Eventually thirteen of the twenty mice inoculated developed tumors. One of them had as many as six tumors; two had four; one had three; six had two; and three had one.

It was later found that foreign-strain tumors which develop after the breaking-down of resistance can be transplanted back into the strain from which they came and will grow in 100 per cent of them. They can also be transplanted in untreated mice of the strain in which they had been introduced, but after one or two "passages" most of the tumors revert to their strain-specificity and thereafter will grow only in the original strain.

It is now clear that there are at least two factors involved in the origin of a tumor: one, the permanently altered cell, and the other, the environment in which that cell must exist. An unfavorable host-environment can be altered so as to permit growth of the malignant cell. But the malignant cell is not thereby essentially altered and it continues to be transplantable into the mice in which it originated. These experiments may add complexity to the cancer problem, but they also give us firmer ground from which to make the next departure.

#### ACID PRODUCTION OF MALIGNANT CELLS

Working with Dr. and Mrs. Lewis, Dr. Amélie Boyd has determined the hydrogen-ion concentration in the supernatant fluid of roller tube cultures in which different strains of tumor and normal cells were growing. She found that all tubes show a rapid fall in pH during the first two hours, which she attributes to an adjustment of equilibrium between the CO<sub>2</sub> in

the air of the tube and the supernatant fluid. Thereafter all tubes showed an increase in the production of acid up to 96 hours incubation. The feature of special interest here is that in this respect the different strains of tumor exhibit individualities. Of five strains, each had its own rate of acid production. Normal fibroblasts used for comparison showed the least proportion of acid. Dr. W. H. Lewis has already emphasized the definite cytological and cultural distinctions which characterize individual tumor strains, and it is therefore of interest to learn these strains also exhibit metabolic differences.

## PHYSIOLOGY OF THE EMBRYO

### EPINEPHRIN CONTENT IN ADRENAL GLANDS OF CHICK EMBRYOS

An advance in the determination of the appearance of epinephrin in embryonic adrenal glands and its correlation to the appearance of chromaffin granules has been made by Mrs. M. R. Lewis and Dr. E. M. K. Geiling. They have found that by making cultures of small pieces of the gland taken from chick embryos of various stages of development (5 to 14 days) and allowed to grow for three days, a progressive increase in the amount of epinephrin takes place amounting to about five-fold the control present at the time of starting the culture. There is at the same time a corresponding increase in the cultures in the amount of chromaffin material and chromaffin bearing cells.

The presence of epinephrine was determined by three tests: blood-pressure changes induced by the injection of an extract of the culture in anesthetized cats; dilation of the pupil when injected in the ventral lymph sac of frogs; and the ferric chloride test for epinephrine.

It was found that chick embryos less than seven days old usually have little effect on blood pressure. Whereas a 3-day culture of the same tissue shows an epinephrine content about equivalent to adrenals of chicks that are left in the incubator for the same length of time. In other words epinephrine develops and acquires its pharmacological properties about as well in cultures of the gland as in its natural environment. This also applies to the chromaffin material with which it is so closely associated. It is to be added that the medium in which the culture grows shows no discernible amount of epinephrine, which therefore is retained within the cells until the extract is made. That it should survive and increase under the conditions of the culture provides us with a better understanding of its nature.

### FUNCTION OF NEPHRIC ORGANS IN THE EMBRYO

To determine if the mesonephros (embryonic kidney) functions and in what manner and at what stages, and to determine its relationship to the functioning of the metanephros (permanent kidney), Dr. I. Gersh has successfully applied indicators of function which can be used in living embryos. To test glomerular activity he injected sodium ferrocyanide. This he found is eliminated almost exclusively through the glomerulus, and can be subsequently recognized by histo-chemical methods. As a test of activity of the convoluted tubules he used phenol red which he found to be eliminated almost entirely by the proximal convoluted tubules. With these two indi-

cators he was able to demonstrate the functional activity respectively of the glomeruli and the tubules, both of the embryonic and permanent kidney and at various stages of development. Furthermore the presence of these two test substances in the lumen of the tubule and duct demonstrates that urine is being formed and eliminated, with a reservation for those instances where the injected material becomes concentrated in the neighboring mesenchymal tissue spaces. Under such circumstances there might be a passive exchange of ferrocyanide ions from tissue to lumen until an equilibrium is reached. This was taken in due account.

In general Dr. Gersh was able to demonstrate, in the rabbit, cat, opossum, chick and pig, that the mesonephros eliminates ferrocyanide (glomeruli) and phenol red (proximal tubules). Also the mesonephros functions for a time even after the metanephros (permanent kidney) has taken on the same functions. As the mesonephros degenerates there is a corresponding loss of function in the respective glomeruli and tubules, and this process gradually proceeds antero-posteriorly. Dr. Gersh hazards the rash suggestion that the primary loss of function and degeneration is the shunting off of the arterial supply to the neighboring structures. This would imply that the blood-vessels were determiners, whereas there is much evidence of their being the most submissive and adaptable of all embryonic tissues.

Dr. Gersh found that when elimination of phenol red begins in the metanephros, one can recognize the differentiation of the cells of the proximal tubules, and this may occur before any elimination of ferrocyanide by the glomerulus. As further differentiation and onset of function of the kidney progresses the new units are found in the outer zone; thus, in the rabbit, cat and pig, the periphery continues throughout fetal growth to show two rows of undifferentiated nephrons; the opossum shows one and in the chick the nephrons are somewhat irregular. Similarly morphological differentiation can be recognized in the loop of Henle as this part of the tubule begins its reabsorption of water. This function usually is established somewhat later than glomerular and tubular elimination.

An important consequence of these clearly planned and carefully executed experiments of Dr. Gersh is the basis which they provide for histological criteria by which tubular function can be determined morphologically in human embryos where experiment is impossible. Comparing human with other mammalian embryos we can now say that tubular function begins in embryos of about 22 mm., or in embryos having a menstrual age of 9 weeks. Also from their histology we can assume that the mesonephros and metanephros overlap in their periods of functional activity. Furthermore on the basis of morphological criteria, the loop of Henle in the human metanephros begins the reabsorption of water in embryos of about 81 mm. sitting height.

As concerns related structures it is to be added that there appears to be no relationship between the structure of the allantoic sac or the placenta and the time of disappearance of the mesonephros. The embryo in its resourcefulness has three ways of urinary secretion: in the chick the products are concentrated in the allantoic sac and retained within the shell; in man and most mammals the urine is eliminated by the kidneys into the allantoic

sac or amniotic sac or both, where it is reabsorbed, both solids and water, to be finally eliminated through the maternal system; and finally in the pouch-young opossum the urine is voided directly to the outside.

### PHYSIOLOGY OF REPRODUCTION

A review of his observations and experiences during the ten years of existence of his macaque colony has been prepared by Dr. C. G. Hartman for the Year Book of the Russian Zoological Society. This was done in recognition of the activity being shown by the Russian biologists in the conduct of a colony of baboons at the Soukhoum Station in the Caucasus. It is assumed that their work and ours will helpfully supplement each other as time progresses.

In looking back, as Dr. Hartman has done, we have reason to feel gratified over the considerable strides that have been made both in the matters of physiology of reproduction and in primate embryology. Many references are made to different phases of this work in the present and previous reports of this department. It can be seen that in these few years Dr. Hartman has met the problems of housing, feeding and handling and has improved the technique of examination and experimentation to the extent that this infrahuman primate is now as available for study and control as any other laboratory animal. Perhaps the most important feature of his report to the Russian Society is Dr. Hartman's statement of the present status of the various problems of menstruation, ovulation, and pregnancy in the light of his wealth of experience with the macaque.

### MENSTRUATION

During the past year the department has been fortunate in having as guest Dr. J. E. Markee of Stanford University. For some years Dr. Markee had been an investigator in the field of the physiology of reproduction, and with collaborators has developed a technique for transplanting bits of living endometrium (uterine lining) into the anterior chamber of the eye, especially in rabbits. The purpose of his visit to us was to apply this type of experiment to monkeys and in cooperation with Dr. Hartman to correlate his observations to the cyclic menstrual changes of the animal and to perform some experiments on hormonal effects.

After the proper instruments and arrangements were installed, Dr. Markee removed bits of the uterine lining in a series of monkeys to the transparent anterior chamber of the eye of the same animal where in each case it secured blood-vessels from the iris and continued to grow. Through the cornea these transplants were examined as often as necessary with a microscope and any changes in them were minutely followed. This amounts to what was otherwise impossible, a continuing microscopic study of the living uterine surface and enables one to make direct observations on the fine vascular changes which characterize that membrane, and which can be correlated with phenomena recorded by palpation and vaginal washings.

It was found that preceding the monthly onset of bleeding, the transplant becomes enlarged and there is a marked vasodilatation and stasis of the blood stream. This is followed by an anæmia of the superficial two-thirds



of the endometrium, which is the region of the "coiled arteries." Some of these coiled arteries constrict before others, but once they have closed the functional layer receives no further blood throughout the remainder of menstruation.

Dr. Markee is of the opinion that this stasis and vaso-constriction bears a causal relation to the bleeding of menstruation. He has carefully studied the escape of blood and distinguishes several types. They consist essentially of successive reopenings of the coiled arteries, for a few seconds to a few minutes, with escape of blood, which in turn is terminated by constriction of the appropriate coiled artery.

In the monkey there is less loss of tissue than in man. Its occurrence, however, can be seen in the transplants. Fragments of completely anemic tissue slowly become detached, in regions where the hemorrhage has ceased. Requiring several hours to detach, these fragments slowly sink to the bottom of the eye chamber where they decrease in size and disappear after four or more hours. Epithelium from the ends of the glands, projecting above the surface of the denuded stroma of the transplant, grows out in patches until the raw surface is completely covered. This then is the surface picture of menstruation, of which heretofore we have had no visual concept. From the behavior of his transplants Dr. Markee concludes that menstruation consists of multiple (perhaps one to three thousand) minute hemorrhages spread over the course of four days and that individually they are very transient. In the monkey transplants, thirty minutes after a hemorrhage all trace of the point of bleeding is lost.

#### OVULATION

There is more or less awareness of the gap between the advance of knowledge and its incorporation in our ways of thinking and acting. A longer or shorter period of conversion seems to have been necessary before advantage was taken of many of the greatest discoveries. This conversion period may be spoken of as the problem of application. The application of discovery is of next importance to discovery itself. Dr. C. G. Hartman has set an interesting example of how the scientist can interpret his own researches so that they are immediately available for general application. In connection with ovulation he has presented in book-form his wealth of observations on that phenomenon in the macaque and, by analysis of related processes in the human as well as lower animals, he has made accessible to the medical profession and educated layman a knowledge of the physiology of the ovary and its relation to reproduction which provides a guide for the intelligent treatment of problems in which these things are concerned. By the study of the macaque where reliance is had solely on objective and controllable tests, he has been able to remove some of the unsound theories which have heretofore beclouded our views regarding the time and factors involved in ovulation. In as much as ovulation is the initial prerequisite to pregnancy, a proper understanding of it becomes a matter of great social significance. Dr. Hartman's contribution on this subject to the medical profession therefore deserves special mention. Though his book is written for the most part in non-technical terms, it can

not be described exactly as a popular book. The reader will find that Dr. Hartman has not hesitated to incorporate in it a great amount of detailed evidence which will make it of value to all students of the physiology of pregnancy.

In connection with ovulation, mention should be made of Dr. Hartman's observations on the rupture of the follicle. In the course of routine rectal bimanual palpation of macaques he has felt the rupture of the ovarian follicle under his palpating finger. This happened in five instances, in each of which the rupture was confirmed either by the time of the ensuing pregnancy or by laparotomy and inspection. The demonstration that rupture of the follicle can be brought about by this means has a bearing on the changes that occur in the follicular wall and Dr. Hartman's observations in these cases thus add further data to our knowledge of the cyclic history of the follicle.

#### EXPERIMENTAL PRODUCTION OF SUPERFETATION

Further observations have been made by Dr. F. F. Snyder of the Department of Obstetrics on the experimental production of superfetation. Using pregnant rabbits with embryos in only one uterine horn, embryo blastocysts were transferred by pipette from another rabbit to the unoccupied horn, and although the first animal had been provided with a second crop of corpora lutea by injection of extract of urine of pregnancy, implantation failed to occur. The original pregnancy must therefore have produced a functional alteration in the uterine mucosa preventing further implantations. To verify this, several blastocysts were transferred in the same manner to a non-pregnant doe in which, likewise, ovulation had been induced five days earlier by injection of urine extract. In this case implantation of the guest blastocysts did occur. The only difference in the two types of experiments was the absence in the latter of the inhibitory effects of the primary pregnancy. This renders the chances of superfetation in man, in the sense of living fetuses of distinctly different ages, as very small.

#### REPRODUCTION IN THE CHIMPANZEE

As a part of his program in the study of growth in primates, Dr. A. H. Schultz has kept for observation and measurement a small group of chimpanzees. They were taken in each instance as relatively young animals and various phases of their adolescence have been studied. Together with Dr. F. F. Snyder, he has made a study of the changes undergone at puberty, the beginning of menstruation and sex life, and adolescent sterility. One case of pregnancy has been studied throughout its course and the data correlated with accounts of other cases in chimpanzees of which there are now a considerable number. Dr. Schultz and Dr. Snyder were able to obtain information on the urine test for pregnancy at various stages of gestation, which had not been adequately done before. They found that the active substance necessary for inducing ovulation in rabbits is present in chimpanzee urine in the early days, but becomes uniformly negative later in pregnancy. That is, it is present throughout pregnancy in man, is present for a time in chimpanzees and is completely lacking in the macaque.

In general it may be said that in regard to the conditions of reproduction the chimpanzee stands somewhere between man and the macaque. In some features, however, such as sex swelling, adolescent sterility and age of first menstruation and first conception, it resembles the macaque more closely than it resembles man. In others, such as duration of pregnancy, and nature of pregnancy urine the difference between it and man is smaller than that between it and the macaque. In respect to the length of the menstrual cycle, man and macaque are more alike than either of them are like the chimpanzee. Thus we have a crisscrossing of specializations and characteristics which are puzzling only to the hard and fast phylogenist.

#### BEHAVIOR STUDY IN THE MACAQUE

In my report of last year I outlined the interesting study being made by Dr. J. P. Foley jr. on the development of behavioral characteristics during the first year of life of a macaque baby reared in isolation from its mother and other individuals of the species. The observations have been continued on the same animal during the second year, the first six months of which the animal was kept isolated. After that it was placed in proximity to other monkeys and was allowed to mix with them. Dr. Foley has thus been able to trace the gradual development of various behavioral complexes and as far as possible has correlated the acquisition of new reaction systems with the particular stimulating circumstances which produced them. He has systematically followed the physical development, the sensorimotor and simple behavioral development. Under the latter he includes, as more significant, such things as feeding, vocalization, prehension, eye-hand coordination, play behavior, tantrums, sexual behavior, and social groupings. The success Dr. Foley has had in rearing this particular animal and the great opportunities he has demonstrated to be possible in the way of observation and experiment under these conditions should lead the way to a much larger use of this approach to the factors underlying the problems of behavior.

#### HORMONE STUDIES

The endocrine glands which play so large a part in the physiology of reproduction are usually referred to in these reports under that section. It is to be remembered, however, that their activities are by no means limited to that phase in biology. Just where they enter into the ontogeny of the body other than modifying the environment is a problem mainly of the future and the embryologist must bide his time. However, as will be seen from the following paragraphs, much of interest is attached to the observations which are possible in the way of comparative studies, in this case regarding the hypophysis.

#### ACTIVITY OF HYPOPHYSEAL TISSUE GROWN IN CULTURE

Utilizing tissue-culture methods, Dr. E. M. K. Geiling and Mrs. M. R. Lewis have succeeded in demonstrating some of the hormonal activity of the different lobes of the hypophysis in mice and rats. Some pieces of them

were grown in nutrient cultures from which extracts were obtained and tested by their effect on blood pressure of cats and on melanophore cells. The tissue of the different lobes of the mammalian hypophysis grow luxuriantly in cultures, and after two weeks or more yield sufficient material to make pharmacological analysis possible.

The mouse was utilized because of the ease with which its intermediate lobe can be separated from the anterior and posterior lobes. In the cultures the three lobes have their own cytological characteristics and their component cells can be identified with the various ones that are found in stained microscopic sections. Therefore reliance could be had on the purity of the cultures. The cultures were allowed to grow for periods varying from three to fifty days, whereon the tissue was removed and an extract made with dilute acetic acid. The extract was then tested for its effect on the blood-pressure readings in the anesthetized cat and for its melanophore-expanding action on frogs.

These investigators found that extracts from cultures of the *pars intermedia* possess no blood-pressure-raising property. They do, however, have a marked melanophore-expanding effect when injected into frogs. Cultures of the anterior lobe neither raise blood pressure nor expand melanophores. Cultures of the posterior lobe (*neural*) in which a little of the intermediate lobe is admixed exhibit both pressure and melanophore-expanding actions. As a control experiment the nutrient medium was shown to have no appreciable effect on blood pressure or on frogs. Also cultures of connective tissue were prepared with known amounts of standard pituitary solution added and it was found that the hormone did not survive apart from its specific cells. Dr. Geiling and Mrs. Lewis have thus restricted the products of the intermediate lobe to a melanophore-expanding hormone and eliminate it as the agent for raising blood pressure, the hormone for which is formed entirely by the posterior lobe.

#### THE HYPOPHYSIS OF SELACHIANS

Using the dogfish and skate where the lobulation of the hypophysis is quite different from the typical mammalian hypophysis, Mrs. Lewis and Dr. E. O. Butcher have tested extracts prepared from their different lobes in respect to the presence of any melanophore hormone. They found that extracts of either the "*pars distalis*" or "*pars intermedia*" when injected into frogs cause an expansion of melanophores. A new complication to the physiology of the hypophysis is thus introduced, since these two lobes are quite different in structure and lie at some distance apart. Furthermore they are separated by the "*pars medialis*," which does not contain any melanophore-expanding hormone. It appears to be true, however, in higher forms whenever an intermediate lobe is present that the melanophore hormone is confined to that lobe; when absent, as in fowls and whales, it is located in the anterior lobe. It is clear that the endocrinologist can not afford to overlook the sidelights on the hypophysis which can be obtained from comparative anatomy and physiology, as illustrated by the studies of Mrs. Lewis, Dr. Geiling and Dr. Butcher.

## STUDIES OF THE NERVOUS SYSTEM

## ABSORPTION OF THE CEREBROSPINAL FLUID

There was occasion two years ago to refer to the studies of Dr. L. H. Weed and Dr. L. B. Flexner on the factors involved in the formation of the cerebrospinal fluid and their conclusion, after a chemical study of the substances of the blood-plasma and of the cerebrospinal fluid, that it is a secretory phenomenon and the cells of the membranes at its source of origin are doing work in its formation. Since that time Dr. L. H. Weed has turned to the other end of the problem, namely, how the cerebrospinal fluid is eventually absorbed. He has been able to show that this is brought about not merely because the venous pressure is usually lower in the superior sagittal sinus than the pressure in the subarachnoid space, but that the absorption is in part conditioned by the colloid osmotic pressure of the blood.

The experimental demonstration of the forces concerned in the absorption of cerebrospinal fluid was made possible by a pipette-reservoir system which Dr. Weed devised and by which any desired pressure can be maintained within the subarachnoid space and at the same time any absorption or extrusion of small amounts of the fluid can be measured. It was found, in the first place, that the rate of absorption of such a fluid as Locke's Solution is markedly accelerated with a three- or four-fold increase in pressure. It was then found that the additions to the fluid of various protein solutions (gelatin, casein and dog serum) give absorption-rate curves having a linear relationship to the Locke Solution curve, providing the effective colloid osmotic value is taken into consideration as well as the effective hydrostatic pressure (the difference between subarachnoid and superior sagittal sinus pressures). The combination of the two gives the total effective pressure. Thus when the absorption rates per minute of a fluid to which a gelatin solution has been added are plotted against the total effective pressure, a linear curve is obtained which duplicates that given by the isotonic crystalloid Locke's Solution under the same effective pressure. That these two are identical indicates that the factors calculated as making up the total effective pressure must be the ones responsible for the process of absorption of the cerebrospinal fluid.

His experiments show that lessening the pull of the osmotic colloid pressure of the blood by increasing the osmotic colloid pressure of the cerebrospinal fluid through the addition of a protein solution to that extent retards the passage of fluid through the absorbing membrane. In this way Dr. Weed has an explanation for the fact that the rate of absorption of a protein solution from the subarachnoid space is slower than that of an isotonic crystalloid solution.

The "effective" colloid osmotic pressure is arrived at by subtracting the colloid osmotic pressure of the modified cerebrospinal fluid, as withdrawn from the subarachnoid space after injection of the protein solution, from the colloid osmotic pressure of the cardiac blood. The determination of both of these is made by use of appropriate celloidin membranes or tubes. Two or more tubes are set up for each sample and the readings made in 20 to 22 hours.

As one of the invited speakers at the Second International Neurological Congress in London, Dr. L. H. Weed gave a report on the advances which have been made during the past few decades in the anatomy and physiology of the membranes of the brain and the cerebrospinal fluid. Along with this he outlined the present problems which now face us in this field. Such a summary by one who has taken so large a share in exploring this difficult field will be of great value to other workers.

#### PYRAMIDAL AND EXTRAPYRAMIDAL FUNCTIONS OF THE FRONTAL LOBES

In the report for last year reference was made to the advance in our knowledge of the pyramidal tract which had been made by the experiments of Dr. S. S. Tower and Dr. M. Hines. By section of this tract at the level of the trapezoid body it was shown that the inhibitory fibers of the tract are separated from the excitatory ones somewhere above that point. These fundamental experiments have been continued and it has been made clear by these observers that the motor cortex and adjacent regions perform pyramidal functions on the one hand and extrapyramidal functions on the other and that the two can be set off from each other by pyramidal section. It is the pyramidal tract (cortico-spinal tract) which mediates the rapidly executed and discrete movements obtained on cortical stimulation, whereas the larger adversive and inhibitory functions are extrapyramidal and are not interrupted by section of the pyramid.

It is to be explained that heretofore experimenters and clinicians have interpreted the results of stimulation and destruction of the motor cortex in terms of excitation and paralysis of the cortico-spinal system (the pyramidal tract). They were unaware of the functions inherent in the extrapyramidal system of which we now know there are several tracts descending from the same cortical area to the brain-stem and from there to the cord. The contribution made by Dr. Hines and Dr. Tower has been the segregation of the very considerable part of the complex activity of the motor cortex which is extrapyramidal from that which is pyramidal. This was made possible by the operative success of Dr. Tower in cutting the medullary pyramid in cats and monkeys. After such a section the deficiencies of the surviving animal reveal the pyramidal functions. The extrapyramidal functions can be identified in the activities retained by the animal and also more directly by electrical stimulation of the cerebral cortex. The experiments show that section of one pyramid results in paralysis of all the muscles of the extremities of the opposite side and also great impairment of muscle tone throughout—typical flaccid paralyses. There remain, however, full tendon reflexes in the individual muscles as well as rigidity, clonus and contracture, all of which are consequently extrapyramidal.

Dr. Hines and Dr. Tower in their survey of the mechanisms of the frontal cortex have demonstrated that the extrapyramidal functions overlap the area of the cortico-spinal tract and spread over a large part of the frontal area and that they operate on the cord indirectly through mechanisms in the brain-stem. Like the cortico-spinal tract, this extrapyramidal system produces both tonic innervation and movement. This motor element is

widely distributed in the cortex and both frontal lobes have to be entirely removed to eliminate the "progression" mechanism. The inhibitory functions, however, of these extrapyramidal tracts are more restricted. Removal of a small area is enough to interfere with the relaxing of objects grasped. Also a small area is concerned with spasticity without grasping. It is also found that these cortical inhibitions may stop activity at various levels; that is, complex performances such as grasping may be stopped high in the brain-stem, while tonic contraction of skeletal muscles can be relaxed at lower levels.

We thus have in the pyramidal and extrapyramidal systems a cortical mechanism of high complexity which functions to facilitate and inhibit activity at all levels of the cerebrospinal axis. And it does this in such a way that the final product of excitation and inhibition of the effector mechanism exactly meets the requirements.

#### SPLITTING AXONES OF THE FACIAL NERVE

Using macaque monkeys, Dr. H. A. Howe and Dr. S. S. Tower have been able to demonstrate that axones from an experimentally injured facial nerve undergo considerable splitting during the process of regeneration, so much so that on return of function the involved facial muscle groups exhibit mass contractions. The muscles of the mouth, nose, eyelids and pinnæ of the ear tend to contract synchronously. The mass movements may involve several of the groups or even all of them. The rhythm of the contractions is in most cases the same as that of eyelid closure. At other times they are slower and synchronize with the dilatation of the nostril during respiration or with the contraction of the mouth and platysma in chewing and emptying the cheek pouches. The degree of this tic-like indiscriminate contraction was found to be in proportion to the amount of damage to the nerve, and the contractions showed no tendency to regression over a three-year period. In the facial muscles of the normal side, as compared with the operated side, a tendency could be seen for a single axone to supply more than one muscle. Such muscles, however, are always contiguous and there is never seen the wide-spread splitting of axones so characteristic of the injured nerve. The experiments of Dr. Howe and Dr. Tower are of considerable clinical interest in that they appear to be an analogous condition to the facial ties which are observed in man after seventh nerve injuries. It was, in fact, for this reason that the experiments were undertaken, at the outset being a cooperative investigation with the late Dr. A. B. Duel. A monographic study covering both the clinical and the physiological aspects was in the final stages of preparation at the time of Dr. Duel's death.

#### DEPENDENCE OF SPIRAL GANGLION ON INTACT ORGAN OF CORTI

In continuing his studies of the ear in deaf albino cats, Dr. H. A. Howe has obtained further evidence that sensory ganglion cells degenerate when deprived of their specialized peripheral endings. In these cats the development of the ear is apparently normal during fetal life and the kittens are born with a normal ganglion cell-count. Subsequently while still young

animals, the organ of Corti undergoes more or less complete degeneration and this is followed by atrophy and reduction in number of the ganglion cells. A close relationship between an intact end organ and an intact cochlear nerve has been assumed, but when they have undergone degeneration, as happens occasionally in man, it has been difficult to determine in which of the two the process originated, the end organ or the nerve ganglion.

In the case of the deaf albino cat, Dr. Howe had the opportunity of studying nine specimens which were of different ages and exhibited different degrees of degeneration. He could thus correlate the age factor with the degree of ganglion cell loss. From the cell-counts in his series one must conclude that the cochlea develops normally in these cats and some time after birth there occurs a progressive atrophy of the hair cells, the destruction extending to all of the cells of the organ of Corti. Still later there occurs degeneration, which is definitely secondary, of the ganglion cells and nerve fibers supplying the end organ. Thus he finds in young kittens the atrophy mostly limited to the hair cells and a ganglion cell-count which is normal. In somewhat older specimens there is complete destruction of the organ of Corti. It is not until after a considerable latent period that reduction in the number of ganglion cells occurs, and this may be as great as half the normal number. If deaf albino cats were not so inconvenient for purposes of genetic studies, they would provide valuable material for experiments in mammalian inheritance. The feature of especial interest would be the histological story of the onset of progressive atrophy in the organ of Corti which up to that moment had developed normally. If it is something in the nature of a premature senility, we seem to have in many other organs and structures of the body processes which are analogous to it.

#### SPINAL CORD OF THE FINBACK WHALE

The whale material brought back by Dr. E. M. K. Geiling from the Queen Charlotte Islands has made possible a number of studies covering various features of this highly specialized mammal. Among them is a study of the spinal cord by Dr. W. L. Straus jr. One of the striking features of this spinal cord is the reduction or slight development of the motor-limb nuclei which is associated with the reduced character of the forelimbs and the vestigial nature of the hindlimbs. The largest groups of ventral horn cells are those concerned with the innervation of the greatly hypertrophied back musculature and those supplying the powerful tail muscles. Apparently these nuclei can be operated with but little cortical direction and the long descending pathways from brain to spinal cord are relatively small.

As for the sensory components of the cord, Dr. Straus finds them feebly represented. The skin of the whale is extremely thick, hairless and more or less insensitive. Thus both the cutaneous and proprioceptive sensibility are poorly developed, and correspondingly the dorsal white columns and the associated horns of gray matter are undersized and the substantia gelatinosa is entirely absent.

The relatively large ventrolateral white columns of the whale spinal cord are regarded by Dr. Straus as in large part made up of intersegmental



fibers serving to correlate the large axial muscles in swimming. This suggestive study of Dr. Straus added to the previous observations of Dr. Langworthy and other investigators of the central nervous system of the whale provides us with material for an important chapter in comparative neurology.

#### ANATOMY OF FLOOR OF THIRD VENTRICLE

In connection with his experimental studies on the production of diabetes insipidus, Dr. C. P. Richter of the Phipps Psychiatric Clinic has given close attention to the anatomy of the floor of the third ventricle. In collaboration with Dr. J. A. Benjamin he has demonstrated, among other features, a hitherto unrecognized thin area forming a pouch where the lumen of the ventricle is separated from the spaces of the meninges by an exceedingly thin membrane. At present there seems to be no developmental or functional explanation for this. However, the relationship occurs in a variety of animals including the macaque. The study of these investigators includes the whole infundibular region. They describe three special areas as seen from the ventral surface and it is the first of these which presents the greatest interest.

### STUDIES IN COMPARATIVE ANATOMY

#### COMPARATIVE ANATOMY OF MUSCLES

Another contribution to his series of studies on the morphogenesis of the shoulder musculature has been made by Professor Brazier Howell. To his work on the shoulder girdle in fishes he has now added the Amphibia. Whereas in the fishes the trend of specialization was toward a fin useful in swimming, in the terrestrial Amphibia it is toward limbs suitable for walking and Mr. Howell points out that it is likely that the change from fin to limb form presented less difficulties for our vertebrate line than the development of an adequate mechanism within the central nervous system whereby progression and the maintenance of posture could be simultaneously controlled. A nervous system which could not provide for this complicated mechanism may well have prevented the ancestors of present-day amphibians from proceeding farther along the tetrapodal line of evolutionary specialization. Since diverging from the main tetrapodal line, the living representatives of this class have had just as long a time to acquire mutant specializations as have the higher vertebrates, and one must therefore proceed cautiously in making phylogenetic interpretations.

In analyzing the homologies of the shoulder muscles, he has depended to a considerable extent on their innervation and his observations are extensive in this direction. He has also supplemented actual dissections with electrical stimulation and in this way has analyzed the reflex mechanisms involved in both locomotion and maintenance of posture. Hereafter we will not be satisfied to discuss muscle homologies without making physiological controls as Mr. Howell has so well done for the amphibian shoulder muscles.

Mr. Howell's studies of the shoulder muscles have been extended to the distal musculature of the arm (or anterior limb). As a means of classify-

ing the evidences of their phylogeny he groups them as derivatives of either the dorsal or ventral "matrix" of the elbow or of the dorsal or ventral "matrix" of the hand (or foot). In these groups and their subdivisions he finds it possible to allocate satisfactorily the various muscle components.

But little attention has been given heretofore to sexual differences in muscle other than the general observation of the slightly greater mass present in males and a few instances where muscles are larger as a part of some secondary sex character. In the common toad it has been recognized that there is a sexual specialization in the male forelimb involving three muscles. Mr. A. Brazier Howell, because of its possible value in experimental studies of sex-gland activity, has studied these interesting forelimb muscles quantitatively. In the three muscles studied, he finds that one of them is 12 to 90 times heavier in the male than in the female and the other two are 72 and 90 times heavier, respectively. This large size is not limited to the breeding season, but appears to prevail at all times.

#### VARIATIONS IN VASCULAR PATTERNS

When variations in pattern and anomalous vessels are met, one has before him only the end results. The factors which led to them are always of great interest to the anatomist because they provide a better understanding of how the normal pattern is derived. Our principal clues have come from what is known of vascular response to changing environmental requirements in the embryo on the one hand and from the recorded data of comparative anatomy on the other. In utilizing the facts of comparative anatomy there has always been the difficulty of distinguishing the significant likenesses from the adventitial. However, the great variety of functional requirements met with in various animals has given us a fertile field in which vascular adaptation can be profitably studied. For a number of years Dr. C. F. DeGaris, along with several co-workers, has been collecting observations of this kind.

Owing to the abundance of monkey material available here, Dr. DeGaris has been able to report on the aortic arch pattern of 133 macaques. The series is large enough to establish a norm for the aortic branches. This norm is found to be intermediate between distinctly human patterns on one side and the distinctly mammalian pattern on the other. The variations are about equally distributed on each side of the norm. By using polygons of frequency, he shows that over 43 per cent fall within the norm, which is characterized by a short "truncus communis." The variants possessing distinctly human patterns account for 22 per cent of the specimens studied, leaving 34 per cent with the prevailing mammalian pattern with some aberrant ones. The morphological criterion on which the pattern is classified rests on how soon the left common carotid artery branches out for itself as an independent artery.

With the assistance of Miss E. M. Glidden, Dr. DeGaris has made a survey of the arteries of the chimpanzee. There were available a sufficient number of specimens to indicate a pattern of the aortic arch essentially like that of the human. Of ten specimens, seven exhibited the usual human sequence of the great vessels and two were like that prevailing in the

macaque. Differing from the human, however, was the presence in eight of the specimens of a "lowest" thyroid artery (a. thyroidea ima). The survey of these investigators included the study of the arteries of the trunk and extremities as seen in one specimen. Their carefully prepared illustrations will make this information available for all those concerned with the vascularization of this animal.

Anomalous arteries in man have been studied by Mr. J. F. Menke, who found a new type of right bronchial artery, and by A. G. Schwyzer and Dr. DeGaris who have analyzed three cases of superficial brachial artery. In Mr. Menke's case a large right bronchial artery arose from the right subclavian artery. In supplying the bronchus it anastomosed with branches of the common intercostal of the same side and so a continuous channel existed between the subclavian artery and the thoracic aorta, a condition which appears never to have been seen before. One might expect it more often because it is somewhat similar to the arrangement normally existing in young embryos, where a right dorsal aorta, from which the subclavian artery is derived, empties into the thoracic aorta at about this level.

The occurrence of superficial brachial arteries is not so unusual. In the three specimens analyzed by Dr. DeGaris and Mr. Schwyzer the causal factors have been interpreted in the light of embryological evidence. It is clear that these vessels are labile in their origin and communications, and their relation in the axillary region to the less labile nerve trunks may result in striking variations in pattern.

#### VASCULAR SYSTEM OF WHALES

During the past winter Dr. R. Walmsley of the Anatomical Laboratory of the University of Edinburgh has been studying as a guest in our laboratory the vascular system of two fetuses of the finback whale, along with supplementary material from adult specimens. The blood-vessels in these marine mammals are highly specialized, and Dr. Walmsley has given a preliminary account of them at the American Association of Anatomists, particularly with reference to their adaptation to the hydrostatic and oxygen requirements which are consequent upon their manner of life. His work is now being brought together for final presentation in the Contributions to Embryology. Dr. Walmsley was enabled to make this study by the award of fellowship by the Rockefeller Foundation. For the material we are indebted to Dr. E. M. K. Geiling.

#### THE SIX LOBES OF THE SELACHIAN HYPOPHYSIS

In connection with the investigations being made of the Selachian hypophysis it has been found by Mrs. M. R. Lewis and Dr. E. O. Butcher that in the cartilaginous fish this gland can be dissected into six well-defined lobes, each quite different in structure from the others. The pars neuralis and pars intermedia are not easily isolated from each other. The other four lobes can be completely separated. These are: (a) pars distalis and (b) pars medialis, representing the anterior lobe; and (c) saccus vasculosus and (d) pars ventralis, specializations occurring in fish. The latter occurs only in cartilaginous fish. Before functional names can be given these lobes, further histological and pharmacological studies will be necessary.

These fish appear to offer an important opportunity for new controls in the determination of the separate hormonal principles contained in the secretions of the versatile pituitary body.

#### THORACIC AND ABDOMINAL VISCERA OF THE ORANG-UTAN

Because of their permanency the comparative anatomist has devoted the greater part of his interest to pelts and skeletons. It is only in recent years that we have begun to survey the primate viscera with greater precision. A study of this character by Dr. W. L. Straus jr. has been published during the past year. It includes an account of the thoracic and abdominal viscera of three orang-utans: an adult, a juvenile and a newborn. Comparison has been made by Dr. Straus between these and data from other sources and other primates, much of which had been assembled by himself. His published study comprises a wealth of material which every teacher of anatomy will wish to have at hand.

When Dr. Straus's observations and collected data are summarized in tabular form, it becomes clear that the viscera of the four anthropoid apes and man possess characters which are essentially peculiar to them as compared with other animals and which in combination offer strong evidence of the genetic affinities of the five animals comprising the group. As for the individual viscera, however, it is seen that they show their highest specialization now in this member of the group and now in that, in an unexpected way. The high specialization occurs in the individual viscus rather than in the animal as a whole. It is pointed out that man is most advanced with respect to duodenum, cæcum, peritoneum and liver, whereas the orang is with regard to lungs and pleura, and the gibbon with regard to position of heart and branches of aortic arch. On the other hand, the gibbon is the most primitive regarding the lungs, cæcum, colon and peritoneum, the gorilla with respect to the form of the liver and man with reference to position of the heart and branches of the aortic arch. In other words, each of the four apes and man is a species combination of visceral characters, some primitive, some advanced and some intermediate, and the evolutionary unit is the viscus or perhaps the components of the viscus. The higher or lower rating of a species must be arrived at by weighing the specializations of its component parts and determining their percentage of theoretical perfection. In this way the relative percentage of perfection of the animal as a whole is arrived at and he can then be placed at his proper level in the scale of aristocracy.

In his survey, Dr. Straus finds nothing to indicate that man possesses any peculiarly close affinities with the chimpanzee-gorilla stock as commonly accepted. He finds man just as closely related to the gibbons.

#### NASAL CARTILAGES IN LARGE APES

In our report issued in 1931 an account was given of Dr. Wen's study of the ontogeny and phylogeny of the nasal cartilages in primates. During the years since then, Dr. A. H. Schultz has collected data on this subject for adult representatives of the higher primates, which were missing in Dr. Wen's study; these have been compared with white and negro adult man. Based on size, shape, character of borders, and topography Dr.

Schultz reaches the conclusion that in these points the cartilages of the anthropoid apes are nearer those found in the Negro than in white individuals. The cartilages in man are proportionately much larger than in the anthropoid apes as would follow from the difference in the prominence of the noses of the two. In the Negro, however, though the cartilages are much larger than in the gorilla, yet there is comparatively little difference in the prominence of their noses. The prominent nose of man is partly explained by the forward projection of the nasal septum, which wedges forward between the wing cartilages. As compared with the Negro the cartilages of white individuals are relatively larger, and the roof cartilage tends to be more nearly quadrangular in shape. These and other characteristics give to the nasal cartilages definite racial differences which can be readily recognized and the range of possible variations in which is unquestionably genetically controlled.

DEPARTMENT OF GENETICS<sup>1</sup>

A. F. BLAKESLEE, DIRECTOR

## DATURA INVESTIGATIONS

A. F. Blakeslee, A. G. Avery, A. D. Bergner, S. Satina,  
J. L. Cartledge and J. T. Buchholz.

## THE SPECIES PROBLEM

Progress has been made in the study of the chromosomal differences between species in the genus *Datura*. The plan of study involves the following program. (1) A survey of the different chromosomal races of each species in nature by a study of the end attachments of chromosomes in reduction divisions in  $F_1$  hybrids between these races and a standard tester for each species. In all species adequately investigated, cryptic chromosomal races have been discovered, the modified chromosomes of which appear to have been derived through segmental interchange. A reasonably comprehensive survey of this kind has been made only in *D. stramonium*. (2) A study of the differences in end arrangements of the chromosomes of the standard testers of each species in terms of the Line 1 standard race of *D. stramonium*. These differences are detected by means of the chromosomal attachments at reduction divisions in  $F_1$  hybrids. (3) A study of the unbalance brought about when the chromosomes of different species are present as extras in our standard Line 1 race of *D. stramonium*. (4) A study of the differences between species in respect to the genes and their arrangement inside the chromosomes. For this study a considerable collection of usable genes has been assembled and the genes are being located in the proper chromosomes by means of various methods for ultimate use as testers in the analysis of the probable internal chromosomal differences.

The study of the differences in the end arrangements of chromosomes in different species is being actively pushed, but difficulties have arisen in obtaining species hybrids in certain combinations. Racial differences exist in respect to crossability. By making many attempts with different races of *D. metel*, for example, a combination has at last been found which gives a fertile hybrid between *D. metel* and *D. meteloides*. At reduction the chromosomes of this hybrid form two circles of 8, one circle of 4 and two bivalents, a fact which indicates that only two chromosomes have the same end arrangements in the races used as components in this species hybrid. To interpret the interchanges involved in the evolution of the chromosomes of *D. metel*, it is necessary to relate the chromosomes to those of our standard Line 1 of *D. stramonium* with which unfortunately *D. metel* appears unable to hybridize directly. An indirect and somewhat tedious method appears possible by the use of *D. leichhardtii* as a "bridging" species since, though the latter does not cross with *D. metel*, it can be hybridized with both *D. meteloides* and *D. stramonium*. With the exception of *D. ceratocaula*, each of the ten herbaceous species of *Datura* in our collection has been shown capable of forming hybrids with at least one other species of the genus, and thus its chromosomal constitution is relatable to that of our standard Line

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1 tester of *D. stramonium*. The program, while theoretically simple, has met a number of difficulties which retard its prosecution. In working over the chromosomes peculiar to our standard Line 1 of *stramonium* into the matrix of *D. leichhardtii* as well as attempting the same procedure with the chromosomes of *D. meteloides*, for example, disharmonies of development appear to have arisen which cause the plants affected to be malformed as if attacked with a mosaic disease. The seeds of *D. ferox*, *quercifolia*, *discolor*, *pruinosa*, and *ceratocaula* are very difficult to bring to germination and this fact adds to the difficulties in carrying on hybridizations involving these species. Miss L. V. Barton of the Boyce Thompson Institute is attempting to discover environmental factors which will increase the percentage of seedlings obtained from our plantings and, if successful, her results will greatly aid the carrying out of our experimental program.

#### SYNTHESIZED NEW "SPECIES"

In previously reported methods of synthesizing pure-breeding types in *Datura*, fragments of chromosomes have been added to the ends of one or more of the necessary chromosomes of the plant and this extra chromosomal material has brought about the peculiarities in appearance of the new races which were thus produced. In these cases the translocated fragments could be identified by matching them with known ends of tester chromosomes. The present method involves adding the extra material inside the chromosome and not at the ends. This has been accomplished in the following fashion. Our standard Line 1 has among its chromosomes a large "l" chromosome 5·6 and a small median "m" chromosome 19·20. By the action of X-rays, segments of these two chromosomes were interchanged so that a prime type race (PT 39) was formed which had an m-sized 5·20 and an l-sized 6·19 chromosome. Through the action of radium treatment, another prime type (PT 53) was obtained which had these same two chromosomes interchanged, with this difference, that the breaks in the 5·6 and 19·20 chromosomes occurred at different loci. As a result the 5·20 chromosome was now l-sized and the 6·19 chromosome was m-sized. In the second case, the ends of the modified chromosomes are the same as in the first case, but the sizes are reversed. In PT 39, the m-sized 5·20 plus the l-sized 6·19 chromosomes have the same genic content as the l-sized 5·20 plus the m-sized 6·19 in PT 53. By crossing together PT 39 and PT 53, an  $F_1$  was obtained which showed two unequal pairs:

$$\begin{array}{c} \text{5} \cdot \text{20} \\ \text{5} \cdot \text{20} \end{array} \begin{array}{c} \text{m} \\ \text{l} \end{array} \quad \text{and} \quad \begin{array}{c} \text{6} \cdot \text{19} \\ \text{6} \cdot \text{19} \end{array} \begin{array}{c} \text{l} \\ \text{m} \end{array}$$

The upper two chromosomes are those of PT 39, the lower two are those of PT 53. Starting with this  $F_1$ , it was possible by proper breeding procedure to eliminate the m-sized 5·20 and 6·19 chromosomes and to replace them by the larger l-sized 5·20 chromosome from PT 53 and the l-sized 6·19 chromosome from PT 39. These plants therefore had two l-sized 5·20 and two l-sized 6·19 chromosomes, but no 5·20 nor 6·19 chromosomes of m-size. The total genic content of these four l-sized chromosomes is more than that of either prime type or than the  $F_1$  between them. Therefore

this new type shows peculiarities in appearance to be expected from the extra chromosomal material which is present inside the modified chromosomes. Such plants show the usual 12 homologous pairs of chromosomes, but in place of the 8 chromosomes of relatively large size and the 4 of relatively small size characteristic of normal plants, they have nine large and only three small chromosomes.

The new pure-breeding type has been synthesized without increasing the number of chromosomes or the number of ends which show attachments in reduction divisions. The excess material within the chromosomes brings about effects upon the appearance of the plant due to chromosomal unbalance. Such synthesized races resemble species formed in nature in that their chromosomes appear normal and their deviations from the types from which they arose are brought about by additions of blocks of genes rather than by changes in single genes. For this reason many characters of the plant are altered rather than only a single character.

#### FACTORS IN MUTATION

Dr. Cartledge has continued his studies on the factors involved in the mutability of *Datura stramonium* under grants from the American Philosophical Society and from the Committee on Radiation of the National Research Council. More precise information has been secured regarding the influence of heat in cooperation with Dr. William Crocker and Miss L. V. Barton, of the Boyce Thompson Institute, who have cared for the treatment of the seeds. An increase in the mutation rate occurs when either moisture, temperature, or duration of treatment is increased while both of the other factors are held constant. The highest rates of pollen abortion mutations obtained from these treatments were somewhat lower than the highest rates obtained by aging seeds.

Since mutations of both pollen abortion and visible recessive genes had been increased by aging and by heat treatments of seeds, similar experiments were attempted by aging and heat-treating the pollen grains before pollinations were made. In a preliminary experiment, pollen stored at 30° C in the air-dry condition was used in making pollinations after periods of aging up to 13 days. About 300 plants grown from the seeds obtained in these pollinations showed very marked increase in their pollen abortion mutations, generally increasing with the age of the pollen and reaching approximately 15 per cent—a higher rate than has so far been obtained for this material by any experimental procedure except strong radiation. In those progenies where small numbers of plants resulted from pollinations with aged pollen, the pollen abortion mutations occurred in about 50 per cent of the individuals.

Experiments are in progress to determine the rate of pollen abortion mutations from seeds made by pollinations with pollen grains that were aged under controlled conditions of temperature and moisture at several levels for each of these factors. The pollen was effective in fertilization after 30 days storage at about 8° C in air of 30 per cent relative humidity; while at 50° C it did not produce seeds after more than four hours storage in air of the same moisture content. The optimum conditions, which would



give effective pollen for fertilizations after the longest possible storage, have probably not been determined. While higher moisture content seems deleterious at the higher temperatures, the present indications are that longer viability may be obtained with higher humidity and lower temperature.

#### STUDIES ON THE FEMALE GAMETOPHYTE

Miss Satina has continued her investigation of the behavior of the female gametophyte of  $3n$  plants with a view to accounting for the number of  $2n$  and  $2n + 1$  types in their offspring, which is much larger than would be expected on the basis of random assortment of the trivalent chromosomes at disjunction. The increase of  $1n$ ,  $1n + 1$  and  $1n + 2$  gametes over expectation is found to be chiefly due to elimination of chromosomes at the I and II meiotic divisions. In 200 megaspore mother cells there were found 52.5 per cent of lagging chromosomes at I meiotic division and about the same percentage of laggards in the II division in 100 megaspore mother cells. In pollen mother cells elimination of chromosomes is a rarer phenomenon. In 100 pollen mother cells only 9 per cent were found at I division.

#### STUDIES IN TASTE SENSITIVITY

During the past summer, with the assistance of Dr. M. Caroline Hrubetz, our studies of taste have been extended. Thresholds of 51 subjects were obtained for 14 substances: ammonium chloride, magnesium sulphate, mannite, saccharin, dulcin, alpha-anti-perilla-aldoxime, oxalic acid, lactic acid, cinchonidine, sucrose-octa-acetate, cetrarin, chloralose, aloin, and phenylthio-carbamide.

The alpha-anti-perilla-aldoxime is the sweetest substance known. It is 8 times as sweet as saccharin and 4000 times as sweet as cane sugar if the relative sweetness is judged by the modes in the distribution curves of the thresholds for these substances. Aloin was detected by some subjects in the extreme dilution of 1:163,000,000 a concentration which approaches the thresholds at which odors are detected. The curves of distribution of thresholds for lactic acid and for chloralose were bimodal and that for aloin was trimodal. It may be profitable to make genetic tests to discover if the differences in taste acuity for these substances have an hereditary basis, as was found to be the case previously reported for P. T. C.

#### THE GENE

*M. Demerec and Margaret E. Hoover*

#### EFFECT OF X-RAYS ON HEREDITARY CHANGES

A large body of evidence is available to show that X-rays are effective in producing gene changes (lethals, most of which are probably deficiencies, and chromosomal abnormalities) and that the numbers of these changes are proportional to the dosage applied. It is also known that lethals and chromosomal abnormalities are frequently produced together.

The salivary chromosomes of 58 deficiencies involving known loci of the X-chromosome of *Drosophila melanogaster* were investigated. The loci involved were yellow, scute, prune, white, facet, cut, vermilion, tan, lozenge,

miniature, dusky, garnet, tiny, forked, bar, and beadex. All of these deficiencies were induced by X-ray treatment with a dosage of 2500 to 3000 r-units.

The lethal deficiencies investigated here probably do not differ from the average lethals induced by a similar treatment. This is indicated by the fact that the proportion of chromosomal abnormalities among such lethals induced by about 2500 r-units was found to be similar to that observed in lethal deficiencies affecting known loci. Thus of the 16 lethals investigated by genetic methods, 5 had chromosomal abnormalities, and of the above 58 deficiencies, 25 were found to be connected with chromosomal abnormalities, either translocations or inversions. In 23 out of 25 cases one breakage point took place in the region in which the deficiency occurred. In only two cases did these two changes occur in different regions of the chromosome. The coincidence of two changes in the same region means that they are both induced by the same local action. This in turn means either that a change to a lethal deficiency frequently induces a chromosomal abnormality, or that the process responsible for the chromosomal abnormality frequently induces a deficiency in addition. If the mechanism which produces lethals is also responsible for the origin of chromosomal abnormalities, then the same proportion of these abnormalities would be expected among lethals which were produced by different X-ray dosages as among those which originated without any treatment. There is ample evidence to show that this is not the case. Among 24 spontaneous lethals tested, none was connected with chromosomal abnormality. To this number 10 can be added which were studied by Oliver with the same result. Among 81 lethals produced by 1400 r-units, 11 or 13.6 per cent were chromosomal abnormalities; among 16 produced by 2500 r-units, 5 or 31.3 per cent belonged to that group; and among 58 produced by about 3000 r-units, 25 or 43.1 per cent were chromosomal abnormalities. These data were obtained in various experiments not designed for the study of the problem considered here and they probably only approximate the actual proportions for the different dosages. They show conclusively, however, that the frequency of chromosomal abnormalities among lethals increases with the X-ray dosage and also that no such change is observed among 34 spontaneous lethals tested. Similar evidence was obtained by Oliver. Since this evidence shows that the mechanism which produces lethals can not be responsible for chromosomal abnormalities and since a part of the lethals originates simultaneously with chromosomal abnormalities, this indicates that the mechanism responsible for these abnormalities is also frequently responsible for lethal deficiencies. Thus, there may be two kinds of lethals produced by X-rays: one type which is formed through chromosomal abnormalities, and the other type which is produced by some other mechanism. Cytological study of salivary chromosomes made on a number of lethals affecting known loci indicates that both types are morphologically similar, *viz.* that both types are short deficiencies involving a few bands. The nature of spontaneous lethals has not yet been studied from this point of view.

On the basis of this study it seems advisable to reinvestigate the quantitative data on the genetic effects of X-rays. These data are based on

the frequency measurements of lethals in which no distinction is made between independent lethals and chromosomal abnormality lethals. For example, the relation between the X-ray dosage and the frequency of all lethals is found to be a straight line, as shown by the independent investigations of a number of workers. From Oliver's data it is possible to separate two types of lethals and when this is done the two new curves are no longer straight lines, but the curve for the independent lethals slopes up and the curve for the chromosomal lethals flattens down at higher dosages. Since Oliver did his work before exact dosage measurements were made, this problem requires reinvestigation. Similarly, none of the studies concerning the effects of different wave lengths took into account the two types of lethals.

In addition to the two types of lethals, X-rays are instrumental in producing visible gene changes. Twenty-eight such changes involving the yellow, scute, white, echinus, crossveinless, vermilion, singed, miniature, garnet, rudimentary, and forked loci were investigated for chromosomal abnormalities. These visible changes were produced by a treatment with 2500 to 3000 r-units. Seven of them were studied genetically and cytologically, fifteen genetically only and six cytologically only. In one case only was a chromosomal abnormality found in the chromosome in which a visible gene change had occurred. Salivary chromosome investigations show that this change is an inversion and also that both breakage points were in regions other than that in which the gene change occurred. These data indicate that the frequency of chromosomal changes is not as high among visible gene changes as it is among lethals induced in the same loci by a similar X-ray treatment.

Accumulation of similar evidence should contribute toward the solution of the question of the origin of various genetic changes and particularly of the question regarding the nature of the action of X-rays. Much detailed study must still be done before a reliable conclusion can be made on this subject.

#### THREE DEFICIENCIES OF THE LEFT END OF THE X-CHROMOSOME

Deficiency 260-5 removes four end bands of the salivary X-chromosome, but does not involve any of the visible extant loci. Flies homozygous for this deficiency are viable and fertile. They do not show any visible peculiarities. The only detectable effect is a decrease in the fertility of females.

Deficiency 260-2 involves a section of at least eight salivary chromosome bands and genetically affects the yellow and achæte loci. As stated in last year's report, this deficiency in the homozygous condition is lethal to the whole organism, but is not cell lethal. The death in the ontogenetic development occurs early in the larval stage.

Deficiency 260-1 involves a section of at least ten salivary chromosome bands and affects the yellow, achæte, and scute loci. In the homozygous condition it is lethal to the whole organism and is also "cell lethal" in females, *viz.* lethal to a small patch of hypodermal cells.

These results indicate that yellow and achæte loci are present in a section represented by four bands (1A5—B1, fig. 1a) and the scute locus is present in a section represented by three bands (B2—B4).

## STUDY OF THE CUT REGION OF THE X-CHROMOSOME

Sixteen deficiencies involving the cut locus were studied by Miss Margaret E. Hoover. All were induced by X-ray treatment. Genetic tests made on fifteen of them showed that no known adjacent locus is involved in any of them. All sixteen were found to be lethal when homozygous. In ten cases studied it has been found that the lethal effect takes place in the late egg and early larval stages. Cell-lethal tests made on ten of the deficiencies revealed none to be cell-lethal.

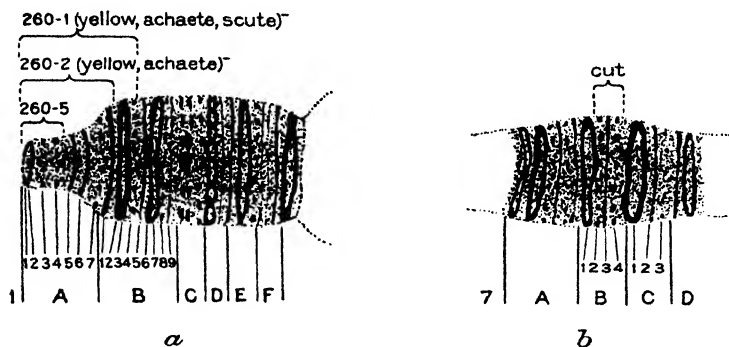


FIG. 1. Diagrammatic drawings of two sections of the salivary X-chromosome of *Drosophila melanogaster*.

a, Left end section indicating regions where yellow, achæte, and scute are located;

b, Cut region of the chromosome.

Salivary chromosome studies showed that in ten cases a chromosomal abnormality occurred simultaneously with a change in the cut region. Six of these are translocations and four are inversions. One of the latter cases is a double inversion, *viz.* a section of the chromosome is inverted on each side of the cut locus, the two chromosomal breakages and the change in cut coinciding.

Salivary chromosome bands were examined in fourteen deficiencies. Cut is located in the 7B section of the chromosome (fig. 1b). In none of the fourteen cases did the deficiency involve either the 7B2 or 7C1 band. This limits the cut locus to one of three bands (7B3 to 7B5).

## FREQUENCY OF CELL-LETHALS AMONG RANDOM LETHALS

Twenty-four lethals induced at random in the X-chromosome by X-rays were tested for the cell-lethal effect, and ten of them were found to be cell-lethal. Out of the fifteen lethals effecting known visible loci, thirteen were cell-lethal. The higher frequency of cell-lethals among lethals affecting visible loci suggests that on the average these loci play a more significant rôle in the vital processes of the organism than do the other loci.

## A FACTOR STIMULATING MUTABILITY

It was found that the natural mutability of the wild Florida inbred stocks of *Drosophila melanogaster* is much higher than that of the stocks which

have been previously investigated. Of the 2108 Florida X-chromosomes tested by the *ClB* method, 23 or  $1.14 \pm 0.16$  per cent of the total proved to carry lethals while of 1627 X-chromosomes from wild Swedish b-stock only 3 or  $0.18 \pm 0.071$  per cent of the total carried lethals. Also of the 1211 chromosomes of the Oregon-R stock tested one had a lethal. The difference in the frequency of lethals between the Florida and Swedish-b stocks is  $0.96 \pm 0.17$ , which is 5.6 times as large as its probable error. These data indicate that the frequency of lethal changes in the Florida stock is six times as high as in the Swedish-b stock.

A *ClB* stock was crossed to the Florida stock twice, *ClB* females being used both times. In the third generation of these crosses males were tested for X-chromosome lethals. All of these males had the Florida X-chromosome. A part of them was homozygous for Florida autosomes, the other part heterozygous. Among the 1338 sperm tested, 4 cases or  $0.30 \pm 0.10$  per cent of the total were lethals. This frequency is probably higher than that observed in the Swedish-b stock, but it is much lower than the frequency in the Florida stock. This indicates that the factor responsible for the increased mutability is nuclear, since the Florida sperm were used in the tests; it also indicates that this factor is not dominant, since only a slight increase in mutability was observed in the material which was a mixture of homozygous and heterozygous Florida chromosomes; it further proves that this factor is not located in the X-chromosome, since all males tested had that chromosome. This factor, therefore, must be situated in the autosomes. Several such factors are known in *Drosophila virilis*, all stimulating the mutability of unstable miniature. Since all of them behave as single genes, it is likely that the mutability stimulating factor in the Florida stock may also be a single gene. Experiments are now in progress to ascertain which chromosome carries this factor.

The mutability stimulating factors known in *D. virilis* are specific, viz. they affect the mutability of unstable miniature only. That the Florida factor is not specific to any single gene is shown by the fact that the 23 lethals obtained from the Florida material were scattered throughout the whole length of the chromosome. However, half of them were located in the cut-vermilion region. This may possibly indicate that the Florida factor does not affect all genes equally, but that it affects some more readily than others.

The positions of the newly found lethals were determined by counts of  $F_2$  generation flies. In these relatively few experiments the following visible mutations, of independent origin, were found: yellow, eighteen times, and vermilion, lozenge, forked, blistered-wings, curled-up wings, and minute once each. This indicates that the Florida factor is effective in inducing visible mutations as well as lethals. The large number of yellows suggests that this locus may be particularly susceptible to the action of the Florida factor, especially since four of these yellows have dark bristles and could hardly be viable deficiencies.

The Florida factor exerts its effect in the germinal tissue of females, since the majority of visible mutations occurred in these cells. It is also effective in the germinal tissue of males, since all lethals occurred in these cells. In

order to test the mutability in other tissues, special stocks are now in the process of building.

### LEUKEMIC STUDIES

*E. C. MacDowell, J. S. Potter, J. Victor, M. J. Taylor, M. D. Findley, T. Laanes, E. N. Ward, M. P. Wintersteiner.*

The cooperative group working in the Department of Genetics and in the Department of Pathology, College of Physicians and Surgeons, Columbia University, has continued to work under a grant to the Carnegie Institution of Washington from the Carnegie Corporation.

### SPONTANEOUS LEUKEMIA

The nature and location of the cell changes that initiate a case of spontaneous leukemia have been unknown because the diagnosis of the disease was possible only after its extensive development. Using a strain of mice in which spontaneous leukemia appears regularly, it has been possible to identify the first cellular changes by a correlation between metabolic and microscopic observations.

Our previous studies have shown that the metabolism of leukemic cells is high; that the metabolism of lymph nodes of mice in this strain rises at a time when it declines in most strains; that at this same age abnormal transformations of reticular cells were found, but their significance was unknown.

Using a technique developed by Dr. Victor that permits the determination of metabolism of minute bits of tissue with great accuracy, the metabolic rates were measured of single lymph nodes removed surgically from a group of 24 mice from this strain. This was repeated at monthly intervals until ten nodes from each mouse had been studied. On removal from the metabolism apparatus every node was sectioned and studied microscopically. When plotted against age the metabolic observations gave consistent curves which rose abruptly in the neighborhood of six months. When the microscopic observations, made without knowledge of age, were correlated with the metabolic it was found that the abnormal reticular cell transformations appeared in lymph nodes whose metabolism had begun to rise, and in no others. By the following month a frankly leukemic condition was associated with the continued rise in metabolism.

Thus the sudden and continuous rise in metabolism, shown by successive observations on the same mouse, directly connects frank leukemia with the abnormal reticular cell transformations, which now can be considered the initial cellular manifestation of leukemia. Reticular cells occur in many parts of the body and the abnormal transformations of these cells have been found in liver and kidney as well as in lymph nodes. The origin of leukemia is not restricted to lymph nodes; it may arise in a wide range of positions and organs. The rapid dissemination of leukemic cells seriously masks the local origin, which, in the case of compact tumors, is usually clear.

### PHYSIOLOGICAL EFFECT OF LEUKEMIA

The cause of death from malignant growth, contrary to a wide-spread view, is not primarily due to mechanical interference. This is well illus-

trated by the enormous leukemic enlargements in spontaneous cases that may live for a long time, compared with the barely perceptible enlargements of a case of transplanted leukemia that may die in three days. In man also, some tumors may persist for a long time, but as in mouse leukemia general weakness and extreme emaciation often appear. The primary lethal effect is physiological.

Direct evidence on the nature of the lethal effect of leukemic cells, as well as a possible interpretation of the baneful activity of other malignant growths, is offered by the discovery that these malignant cells exert a depressing effect on the metabolism of normal tissue. The metabolism (anaerobic glycolysis) of peripheral lymph nodes removed surgically from the same animals before and at different times after inoculation with leukemic cells, showed a depression after inoculation which lasted until leukemic cells were found in the nodes. Thereupon began a rise in metabolism that continued with the increase in leukemic infiltration until the high value characteristic of the particular leukemic cells was reached.

The genetic and developmental uniformity of the mice used, the rigid comparability of the values for lymph nodes taken at different times from the same animal, the full knowledge of the behavior and characteristics of the specific lines of leukemic cells used, the microscopic and metabolic study of the same individual nodes—these conditions give a high degree of control upon this result. The number of observations is ample and the main point may be considered as established. However, many questions stand open: these bear on the distribution of this depression among lymphoid and other tissues at given times; the mechanism transmitting the effect, whether a direct product of the leukemic cells, or of the host; how far other tumors in fact call forth a similar reaction.

A corollary of this result is an independent confirmation of an earlier conclusion based on microscopic observations, that transplanted leukemic cells do not stimulate host tissues. The pedigree of leukemic cells goes back to their origin in a spontaneous case, uncontaminated by contributions from the hosts through which they have passed.

#### STUDIES ON INDUCED RESISTANCE

Last year we reported the induction of resistance in a given strain of hosts against a given line of leukemic cells following treatment with normal embryo tissue of a certain genetic constitution. Further experiments show that embryo tissue of a given constitution may give different results as the genetic constitution of the host is varied. Embryo tissue of a constitution that fails to induce resistance in hosts of one strain may do so in hosts of another strain; again, embryo tissue which induces resistance in hosts of one strain has been found to hasten the development of transplanted leukemic cells in hosts of another strain. In this last case the tumorous enlargement of the spleen and death occur significantly earlier than in the closest possible control animals (born in the same litters, living throughout in the same boxes and inoculated with the same suspensions of leukemic cells).

Thus treatment with embryo tissue may lead to surprisingly different results, which depend upon an interaction of the host and the embryo tissue rather than directly upon a substance already present in the embryo.

Many experiments have been carried out this year on the nature of the process of resistance induced by embryo tissue. The time required for this resistance to be built up has been a fruitful approach to this question. When the embryo treatment is given in the usual manner, using a combination of host and embryo strains that yield resistance, and when the leukemic cells are introduced into different mice after different intervals, it has been found that there is no protection at all when the leukemic inoculation is given at once or after one day; when given two days after the embryo treatment an occasional mouse may survive, showing that the protective process has begun. At three days every mouse is resistant, but at four days the resistance is suddenly reduced, for many of the animals die. With progressively longer intervals before the leukemic cells are inoculated the proportion of survivors gradually rises to a second maximum in the third week. At two months some resistance still persists, but it is considerably reduced. Thus the graph of the proportion of survivors plotted against the number of days between the administration of embryo tissue and leukemic cells shows two modes separated by a deep valley; the first is an abrupt pinnacle centered at three days; the second, a plateau, gradually rounded off on both sides.

Two processes are clearly operating; the difficulties of analysis are immediately multiplied. The high effectiveness of the three-day process and its prompt loss of effectiveness suggests a direct action upon the leukemic cells by some temporary breakdown product of the embryo tissue as controlled by the conditions within the host. The second process, developing more gradually and persisting for a considerable time, gives the impression of resistance due to a modification of the host. Are these two processes initiated by the same or different primary steps? Are the active agents (or agent) generated from the embryo tissue as acted upon by the host, or vice versa, or in both ways?

Within the host the effective embryo tissue is soon killed, and yet if the life of this tissue is destroyed before entering the mouse by freezing, by high temperature or by alcohol, the protective potency is completely lost. Within the host some autolytic action is almost certainly involved, and yet when autolyzed outside the host the embryo tissue does not yield a substance capable of protecting the mouse by direct action on leukemic cells when the cells and the autolyzed embryo tissue are injected successively into the abdomen of the host.

Before inoculation with leukemic cells the mice treated with embryo tissue show no microscopic evidence of the treatment; the blood picture and hypertrophied thymus, characteristic of mice immunized by leukemic cells, are lacking. After leukemic cells are inoculated, they can not be found in embryo-resistant mice; they fail to proliferate to the extent of forming lesions, while in mice immunized with leukemic cells, proliferation takes place, lesions are formed and then suppressed in a manner reported last year. The only observed reaction of the embryo-treated hosts to the leuke-



mic cells was an overgrowth of connective tissue, usually in perivascular sheaths. This occurred particularly in the liver where this hypertrophy sometimes invaded the lumen of the vessels, causing blockage and death of the region.

Resistance due to embryo-tissue treatment involves two processes; resistance developed by repeated small doses of leukemic cells is still another process, contrasted in the time required for its development, in its persistence, and in the initial fate of the inoculated cells, and, as follows, in the final fate of these cells.

A still further difference between the two methods of inducing resistance is that a mouse protected by small doses of leukemic cells completely and finally suppresses the inoculated cells, while protection by embryo tissue is frequently only temporary. Although the malignant cells are not demonstrable, since lesions are not formed, there is no reason to doubt their presence in a suppressed state; subsequently, as the resistance wears off, these may develop into well-expressed lesions consisting of cells characteristic of the particular leukemic line originally inoculated.

#### MODIFICATION OF LEUKEMIA

Beside these delayed cases of leukemia, embryo-treated mice that have resisted leukemic inoculation may develop well-marked lymphosarcomata (to date 101 cases). These are typically flattened, progressive tumors lying near the skin in any part of the body; they readily enter muscle; they may be single or multiple, scattered in many positions and in different stages of development from mere red dots on the skin to thick pads covering a whole body region. Histologically they show a large proportion of connective tissue contributed by the host, with well-developed vascular organization; the malignant cells have become markedly different from those of the line inoculated. The metabolic rates of these tumors are approximately those of connective tissue; the oxygen consumption being reduced to about a tenth of that usually found for leukemic tissue. These tumors may occur alone or associated with frank leukemia.

That these lymphosarcomata are in fact transformations of leukemia and not of independent origin is well substantiated.

(a) Spontaneous lymphosarcomata have never appeared at the age of the cases under consideration nor have they appeared as flattened peripheral pads; in any case they are very rare, while these lymphosarcomata are very frequent under the given experimental conditions.

(b) The technique of transplantation and inoculation has been maintained constant throughout so that the occurrence of these lymphosarcomata is an entirely different phenomenon from variation in the concentration or dispersion of lesions due to inoculating the leukemic cells in different sites.

(c) The most convincing evidence of all that these lymphosarcomata are transformations of leukemia is the reappearance of leukemia when these tumors are transplanted into untreated mice. Thirty-one of these tumors have been tested by transplantations into hosts genetically alike but untreated; in the great majority of cases, leukemia appeared in every mouse. Furthermore, the leukemia presented the characteristics of the particular

leukemic cells that had been inoculated into the donor of the tumor. The distribution of lesions, the cytological characteristics, the metabolic rate, were all as before. By the second transfer, the first in which the dosage could be controlled, the interval before death became characteristic of the line of leukemic cells used.

The reappearance of the particular leukemia started with indicates that the embryo-treated hosts have power to modify the form and action of the malignant cells temporarily, but evidence has appeared of a more lasting modification in the occasional reappearance of tumors in the transfers from a tumor-bearing host; and in one case, the tumor has continued to reappear in all mice in 5 (to date) successive transfers.

The embryo treatment suppresses rather than exterminates leukemic cells; but this protection is not lasting. As it breaks down, the liberated cells may proceed to typical leukemia or, with only partial liberation, cells may stimulate a connective tissue reaction, especially in peripheral regions, and lymphosarcomata are formed. These tumors may or may not result in an inherent change in the malignant cells. These lymphosarcomata are partially suppressed leukemia.

That lymphosarcoma is closely related to leukemia has long been clear, but the relationship now established is much closer than had been supposed. In man, both conditions have appeared in the same individual, but whether these were different manifestations of the same primary agent or parallel occurrences of two similar agents could not be known.

The importance of extrinsic agencies in the control of malignancy becomes more and more certain. The delicacy and potency of the interactions of embryo tissue and hosts, upon which the present study is based, lead into new fields in which genetics and chemistry will have to travel together.

### ENDOCRINE STUDIES

*O. Riddle, R. W. Bates, J. P. Schooley, G. C. Smith, E. L. Lahr  
and M. W. Johnson*

The part played by hormones in the development of all higher organisms, and in the maintenance of normality and health in man, gives importance to new knowledge of the nature, number and action of these substances. The secretions of the anterior pituitary gland are now receiving attention in many laboratories, and during the past year they have been the center of interest for Dr. Riddle and his associates.

Several of the investigations reported here have a common result in their indication—contrary to much current belief—that the pituitary produces very few instead of a dozen or more hormones. These studies have been greatly aided by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

#### HORMONES OF THE ANTERIOR PITUITARY

This year—through exchange of pituitary preparations (our prolactin and the adrenotropic fraction of Collip) with Professor J. B. Collip of McGill University—it has become more probable than before that the names, prolactin and adrenotropic, have been applied to the same substance. Thus pro-

haps the number of alleged hormones is reduced by one. When Collip and Anselmino and Hoffman first showed the stimulating and reparative action of a pituitary fraction on the adrenal they did not recognize the active substance as the (earlier isolated and named) prolactin of Riddle and Bates.

In collaboration with the laboratory of Dr. E. C. McDowell a study made with dwarf mice by Dr. Bates, Mr. Laanes and Dr. Riddle has supplied evidence that the influence of the pituitary upon body growth is not exerted by a single hormone ("growth" hormone); that prolactin and thyrotropic hormone each causes some growth in this dwarf; and that when these two hormones are administered together to dwarfs they act synergistically upon body growth. The probable dual or composite nature of "growth hormone" was pointed out last year. Now this same view of the pituitary's contribution to body growth is supported by the above noted new evidence that prolactin stimulates and repairs the adrenal glands. There was an initial strong presumption that whatever the pituitary contributes to the support, stimulation and repair of the adrenals and thyroids will contribute to body growth. Since it appears that no potent preparation of "growth" hormone has yet been made free of both prolactin and thyrotropic hormone the facts stated above, together with other facts reported last year, make the existence of a separate or individual "growth" hormone extremely doubtful.

One pituitary principle which increases the amount of sugar in the blood (and urine) has been identified as prolactin by Dr. Riddle and by Dr. Louis B. Dotti, of Columbia University, who has been associated with this Department during the past two summers. In hypophysectomized pigeons 20 or more hours may elapse after an injection of prolactin before the rise in blood-sugar begins, but in normal pigeons fasted 24 hours the rise begins early and attains a maximum 24 to 48 hours later. The response is obtained in doves, fowl, rabbits (but not in rats) and in normal, hypophysectomized and thyroidectomized pigeons given 10 to 60 units daily of prolactin from one to four days. In the non-fasted pigeons (80 tests) increases of 6 to 30 per cent, and in fasted pigeons (41 tests) increases averaging 27 per cent have been obtained. Hypophysectomy (27 tests) results in a moderate decrease in blood-sugar; this deficiency of about 10 to 20 per cent is restored and exceeded following injections with prolactin. Many tests have shown that follicle-stimulating and thyrotropic hormones do not increase the blood-sugar. Earlier investigators, using mixed or crude extracts, have supposed that a separate "diabetogenic" hormone was involved in this capacity of pituitary extracts to augment sugar in blood and urine. It is now very probable that the diabetogenic response is assignable to prolactin, not to an additional or separate pituitary hormone. It is notable that this action of prolactin on carbohydrate metabolism is almost certainly exerted indirectly through the adrenals. In both normal and hypophysectomized pigeons twice-daily injections of cortin increased the blood-sugar (17 tests) by 10 to 20 per cent. In the hypophysectomized animals (7 tests) no increase was obtained at 3 days, but after 10 daily injections an increase of 20 per cent was found.

It has also been shown by Riddle and Dotti that the follicle-stimulating hormone may now be considered the pituitary hormone which—probably

acting through the gonads and parathyroids—causes increased amounts of calcium to appear in the blood serum of doves and pigeons. Thus an alleged “parathyrotropic” hormone of the pituitary appears as a synonym of the earlier known gonad-stimulating, or follicle-stimulating hormone. All pituitary extracts—crude or refined—which are rich in gonadotropic principle (36 tests) have been found capable of increasing the serum calcium in suitable pigeons. The fasting state, sexual immaturity and maleness all seem to reduce or to erase the calcium-increasing power of the hormone (71 tests). The serum-calcium level is decreased by hypophysectomy by about 10 per cent (31 tests). Prolactin, in moderate and high dosage, has shown no effect on the serum calcium (72 tests) of normal, hypophysectomized, thyroidectomized pigeons, normal rabbits, fowl and rats.

In August of last year some essential parts of these and other studies of this laboratory were presented before the XVth International Physiological Congress in Leningrad and Moscow. During an absence of ten weeks in connection with attendance at this Congress, Dr. Riddle visited many laboratories in 14 countries, including practically every laboratory in Europe where significant work on the anterior pituitary gland is being done. Contacts and information obtained in this way have assisted and in some respects modified the activities of our laboratory during the present year.

#### FURTHER STUDIES ON ACTION AND FUNCTIONS OF PROLACTIN

Lyons and Page of the University of California recently showed that when very minute amounts of prolactin are injected *into* (not beneath) the skin which lies directly over the crop-sacs of pigeons the walls of these crop-sacs become stimulated. Our published method for the quantitative assay of prolactin is based upon four daily injections of the prolactin-containing extract into the pectoral muscles and removing and weighing the crop-glands 96 hours after the first injection. The work of Lyons and Page led Bates and Riddle to a further study of the effect of route of administration of prolactin on the amount of crop-gland stimulation. Using 125 pigeons of the same race and age they obtained widely varying results from five different routes of administration. Subcutaneous and intracutaneous injections are thus found to be about 11 times as efficient as intravenous, about 5 times as efficient as intramuscular and about 8 times as efficient as intraperitoneal injections. It is not yet known whether subcutaneous injections in the parturient woman will be similarly more efficient in inducing lactation; if this later proves to be the case the cost of medication with prolactin should be considerably reduced.

Results reported last year by Riddle, Lahr and Bates showed that maternal behavior in young male and female rats can be initiated by injections of prolactin, and by that pituitary hormone only. The study of this subject has been actively continued and others have meanwhile reported upon certain aspects of the induction of maternal, or parental, behavior in rats and mice. Williams, of California, found that removing the thyroids of male rats led to such behavior and Leblond and Nelson of Yale University recently reported that a slight but definite appearance of the patterns of parental instinct usually appears at puberty in both male and

female mice. We have confirmed the report of Williams that thyroidectomy of male rats results in the exhibition of parental care of young, and have further found that removal of the pituitary in young virgin rats is followed by maternal behavior in most (12 of 16) tests. The seeming paradox involved in obtaining the same result by injecting prolactin, and by completely removing prolactin and all else contributed by the pituitary, remains a challenging question. Still other observations have now shown that injections of the hormone of the corpus luteum (progesterone) into virgin rats is very frequently (in 16 of 22 tests) followed by maternal behavior; and in the only two tests conducted on hypophysectomized virgins this result was likewise obtained. A study of this point is being continued.

Though our reports of previous years have indicated very striking adverse effects of prolactin upon the ovaries and testes of birds, we have been unable hitherto to demonstrate any similar adverse action in mammals. During the present year, however, Lahr and Riddle have shown—following a similar demonstration by Dresel in mice—that prolactin temporarily suppresses the estrous cycles of rats. In these tests about 3 cycles were suppressed following the initiation of daily dosage with 15 to 30 units of prolactin; thereafter, though dosage was continued, one or more normal cycles occurred; these cycles in turn were followed by a further period in which about 3 cycles were suppressed. The ovaries of rats whose cycles were suppressed for 10 to 12 days had well-developed corpora whose large cells showed no clear evidence of degeneration. Such cells suggest a continued production of progesterone; but when moderate dosage of progesterone was injected into similar rats, no suppression of cycles occurred. Others have shown that huge doses of progesterone will suppress estrous cycles. The chief significance of this study is found in its demonstration that prolactin, directly or indirectly, does affect the rodent ovary—and in the sense that it diminishes its primary activity.

During the past three years Riddle and Bates have accumulated much evidence that injection of prolactin, and of this pituitary hormone only, leads to marked and rapid increase in the size of the liver in doves and pigeons. Though the character of this evidence does not lend itself to summary treatment here we cite results from adult ring doves injected for 10 days with higher and lower dosage with prolactin, with muscle extract controls, and with a prolactin-free mixture of follicle-stimulating and thyrotropic hormones. Muscle extract controls (10 tests) gave average liver weight of 3.10 grams; high prolactin dosage (7 tests), 8.16 grams; lower dosage (103 tests), 5.51 grams; F. S. H. + thyrotropic (9 tests), 3.51 grams.

In an earlier section of this report it is noted that prolactin has now been identified as one pituitary principle which increases the sugar in the blood; also that exchange of pituitary preparations with Professor Collip has suggested the identity of prolactin and the adrenotropic fraction. Notable also in this connection is the fact that prolactin sent to Dr. B. O. Barnes of the University of Chicago was found to produce marked glycosuria in hypophysectomized-depancreatized dogs. Similarly, Professor C. N. H. Long, George S. Cox Medical Research Institute, Philadelphia, later found

that prolactin sent to him for such tests produced glycosuria in hypophysectomized-depancreatized cats, but failed entirely to affect the sugar values in adrenalectomized-pancreatized cats. This latter demonstration brings apparently conclusive evidence that prolactin acts upon the adrenal, and indicates that its effect upon sugar metabolism is probably exerted through the adrenal.

When one now recalls the several actions—primary or secondary—of the hormone which Riddle, Bates and Dykshorn isolated, described and named “prolactin” in 1932 it becomes clear that a name less associated with lactogenesis (mammary and crop-gland secretions) might have been more appropriate. In addition to those two responses prolactin has now been found (3) to exert an adverse effect (direct or indirect) on functioning gonads and (4) a reparative action on adrenals, (5) to release the incubation instinct in fowl and the parental instinct in young rats, (6) to increase the basal heat production in thyroidectomized animals and to act synergistically with thyrotropic hormone on the B. M. R. of pigeons, (7) to promote growth in some animals and to act synergistically with thyrotropic hormone on body growth in dwarf mice, (8) to induce (probably indirectly through the adrenals) glycemia and glycosuria, and (9) to cause prompt and marked enlargement of the liver in at least some animal species. Though it is still too early to suggest a name that would best characterize the several actions of prolactin the fact that its administration is already known to call forth nine different responses is a fair indication that all of the many regulations effected by the anterior pituitary gland may be accomplished by very few hormones—probably only three or four.

#### STUDIES WITH FOLLICLE-STIMULATING HORMONE

Use of increase in testis size in the biological assay of follicle-stimulating hormone (F. S. H.) gives importance to a consideration of the structures involved in the rapid testicular growth which accompanies the administration of all extracts rich in that hormone. Such a study has now been made by Lahr, Riddle and Bates. Testes stimulated by our numerous F. S. H. (+ thyrotropic) pituitary preparations, by the F. S. H., or by the “luteinizing” preparations of Fevold and Hisaw, by serum of the pregnant mare, by whole pituitary extract, and by male urine of a subject with embryonal carcinoma of the testis, all show a pronounced growth of the tubular tissue after 4 daily injections. With this degree or duration of treatment intertubular spaces may be more or less evident and intertubular tissue little if at all increased. More prolonged injections rapidly develop and differentiate the germinal epithelium, and the fluid-filled interspaces either disappear completely or become negligible. Our evidence indicates that each of the above-named preparations is capable of inducing complete spermatogenesis in a 2-month dove or pigeon testis by 14 daily injections.

A study of the action on fish ovaries and testes of follicle-stimulating hormone derived from cattle pituitaries, from the serum of the pregnant mare and from pregnant urine, has been made by Dr. Riddle and Dr. Johnson with wholly negative results. Rainbow trout, maintained in their normal state through the courtesy of Mr. Stanley Walters, of the adjacent New York

State Fish Hatchery, were tested at the age of 11 months (Nov.) and again at 16 months (April). The 29 males and 36 females given the above preparations intramuscularly (peritoneally in 6 cases) daily for 15 to 22 days had ovaries and testes whose weight and histology differed in no detectable way from the gonads of 25 fishes which served as controls. It is of considerable theoretical interest to know whether the gonads of fishes respond to the same hormone that is effective in higher vertebrates, and the study will be continued on the same brood of trout at a still more advanced age.

#### EFFECTS OF PITUITARY REMOVAL IN PIGEONS

In only 9 or 10 species of animals do we have even a fair amount of information as to effects of total removal of the anterior pituitary gland upon the various organs and functions of the body. An attempt to supply information for the pigeon has been made by Dr. C. S. Moran and Dr. Riddle. While connected with this Department, Dr. Moran was able to obtain data on body weight and organ weight changes in a large group of operated (103) pigeons and to make observations on the histology and pathology of several organs of 22 of these animals; still other information on various disabilities and functions of these and still larger numbers of operated animals have been made by Dr. Riddle and associates. Changes and disabilities following this operation in pigeons are essentially similar to those earlier found in higher animals. Further study of some of these post-operative changes, and the current task of extirpating the pituitary gland from certain birds of our colony, have been undertaken by Dr. Schooley.

#### CYTOLOGICAL BASIS OF PITUITARY HORMONE PRODUCTION IN PIGEONS

In female pigeons the cycles of reproduction are especially well marked, and in our bird colony the easily recognizable stages or phases of these cycles are continuously recorded. A study by Dr. Schooley and Dr. Riddle has attempted an analysis of the functional state of anterior pituitary cells by checking their purely cytological manifestations in two ways. First, by the clearly correlated changes occurring in organs known to be controlled or activated by pituitary hormones. Second, by daily transplants (one daily for 5 to 10 days) of pituitaries of known stage and cytology into immature male ring doves whose organ responses are capable of revealing the quantity of prolactin, follicle-stimulating hormone and thyrotropic hormone contained in the transplants. Using these bases of interpretation it is found that basophils are in a state of active excretion (degranulation) coincident with the phase of extremely rapid growth in ova. Acidophils assume secretory activity near the time of ovulation, and they increase in excretory and secretory activity during incubation and early days of feeding young. This evidence supports the current view that the follicle-stimulating hormone is produced by the basophils. Acidophils appear to be the source of prolactin, and since they have been regarded as the source of "growth hormone" support is found for the view that the growth principle is a composite rather than an individual. The study was based on 178 pituitaries.

## ABNORMAL SEXUALITY IN PIGEONS

A quite exceptional and instructive case of hereditary hermaphroditism in pigeons has been found and described by Dr. Riddle and Dr. Schooley. The parents of this particular family are a brother and sister who, though still alive, have been found by biopsy to be a unilateral hermaphroditic male and a normal female. Their father and mother in turn were normally sexed, as were all their near relatives. The 25 offspring of this pair included 8 normal males, 11 normal females, 5 true hermaphrodites, and 1 male whose abnormality—when killed at the age of 3 months—consisted in the presence of a left oviduct and a left testis accompanied by considerable residual Wolffian tissue. Only the character and variety of the hermaphroditism displayed in these cases is further noted here. Though this hermaphroditism clearly has a heritable basis, the abnormal sexuality is exhibited in quite unlike degrees within the six abnormally sexed members of the fraternity. The abnormal male with two testes, but with a left uterus and residual mesonephric tissue, represents the lowest grade—but a grade frequently reported by Riddle in earlier studies on the “all-male” offspring of pigeon crosses of family rank. A second grade is represented by two individuals with ovotestis and oviduct on the left side. A third grade by this condition repeated with the addition of a very small oviduct on the right side; a fourth grade by ovotestes on both sides and a good oviduct on the left side with a minute one on the right side. Thus in every case the “feminine” quality was more emphasized on the left side of the body than on the right.

Four years ago Riddle reported a peculiar type of sex abnormality found regularly among the offspring of a sub-family cross ( $\delta$  *Zenaidura* X  $\eta$  *Streptopelia*) of pigeons. During the present year Riddle and Johnson have completed a histological survey of the gonadal conditions found in young and old of 134 offspring of this cross. Of this number 83 were normal males and 51 were of the type which were apparent females at hatching but later became intersexes. The essential normality of the testes of the group of males is demonstrated. In the new-hatched bird of the abnormal group the single left gonad, which has the unpaired character and the form and shape of an ovary, is then not fully or truly ovarian, though it more closely approximates to ovarian than to testicular tissue; its differentiation seems to have been retarded even prior to hatching. At this and all later stages of life this left gonad is accompanied by a patent unpaired oviduct. In adult birds of this type, killed in spring or summer when gonad development should be at its height, the left gonad is extremely rudimentary; it has neither ova nor distinguishable ovarian tissue, but does then contain incompletely differentiated testicular tubules. The history and histology of the reproductive organs of the sexually abnormal offspring of this cross show that they must be considered genetic females which have developed into intersexes.

## BASAL METABOLISM OF DOVES AND PIGEONS

The study of the metabolic differences associated with race, sex, age, hybridity and reproductive state was continued to the end of 1935 in col-



laboration with Dr. F. G. Benedict, director of the Nutrition Laboratory, and with the assistance of Mrs. Guinevere C. Smith. Newer knowledge of the pituitary gland as a background for metabolic differences is now receiving a large share of attention, and investigations within this field require orientation studies on which progress is slow. A current attempt to determine the "critical" temperature of hypophysectomized pigeons and of thyroidectomized pigeons is an example—and here the obligation to clarify the subject is imperative since there is no warrant for an assumption that this value remains the same in any animal after either of these operations. Though considerable effort has been expended on this problem it is now possible to state only that in at least some races of pigeons the "critical" temperature for both thyroidectomized and hypophysectomized pigeons is 25 to 27° C.—not at 30° C. as currently accepted for normal pigeons.

Since, as already noted, prolactin has an action upon the basal metabolism, and also acts upon the adrenal cortex, it was thought of much importance to learn whether cortin—the best known hormone of the adrenal cortex—has an action upon the basal metabolism similar to that of prolactin. Though no quantitative expression of the potency of the cortin dosage is available, and though no tests have been made of its action at low temperature (15° C.), our measurements made at 25° and 30° C. show increases of 4 to 6 per cent in hypophysectomized pigeons and in normal ring doves. In these same animals there was a simultaneous increase (10 to 20 per cent) in the amount of sugar in the blood.

## STUDIES IN EUGENICS AND HEREDITY

*H. H. Laughlin*

### A NEW PAN AMERICAN WORK-MAP

During the year the new Master Map of Pan America was completed by the United States Coast and Geodetic Survey in collaboration with the Eugenics Record Office.

#### THE STANDARD GRID

The new Pan American map has been covered by a standard rectangular grid composed of 215 equal primary squares. When superimposed upon the map of the Western Hemisphere drawn upon this new Pan American projection, any given grid-square represents coverage of a constant area on the actual earth's surface regardless of where the particular square may be placed. Each primary grid-square represents an actual area equal to a square which measures 1000 kilometers on one side; the secondary grid-squares 1/10th as much or 100 kilometers on a side; the tertiary grid-squares 1/10th as much as the secondary or 10 kilometers on a side; and so on to any desired degree of metric subdivision.

#### USE OF THE STANDARD MAP AND STANDARD GRID

Tables have been computed for the correct geodetic latitude and longitude for the four corners of each of the 215 primary grid-squares, and formulæ are given for determining the latitude and longitude of the four corners of any subject-square of the second, third or lower order of sub-division.

Thus for convenience in geographic or historical researches with the Pan American Master Map and the super-imposed grid as a tool, any Pan American geographic data plotted on maps, or otherwise located geodetically, can be coordinated with the Standard Grid-square System of the Master Map for the purpose of indexing and for computing the Index of Resemblance in Geographic Distribution. The one standard necessary for such coordination in any Pan American area is thus supplied by the Master Map and the Standard Grid, and in coordinating with such standard any Pan American map, drawn on any other projection system or scale, it is the particular grid-square and not the map which is distorted to represent the specific area on the earth's surface.

1 29	2 29	3 28	4 29	5 31
6 28	7 29	8 30	9 32	10 33
11 26	12 30	13 32	14 32	15 33
16 25	17 27	18 30	19 35	20 36
21 25	22 30	23 36	24 38	25 37

1 50	2 50	3 55	4 60	5 60
6 50	7 55	8 57	9 60	10 65
11 52	12 57	13 60	14 62	15 66
16 53	17 58	18 60	19 65	20 69
21 50	22 60	23 70	24 80	25 75

### INDEX OF RESEMBLANCE IN GEOGRAPHIC DISTRIBUTION

One of the main purposes for preparing the new equal-area Pan American map and standard grid is to facilitate the computation of indices of resemblance in geographic distribution between pairs of measurable traits or qualities distributed over the same geographic area. As a type or pattern this problem and its proposed solution are stated as follows:

To Compute the Quantitative Index of Resemblance in Geographic Distribution—

#### GIVEN:

- Case I. Two qualities each definitely enumerated or measured for each sub-area within the one composite area;
- or Case II. One quality independently enumerated or measured for each equal sub-area within each of two different but geometrically similar and homologously subdivided composite areas regardless of their relative size or orientation;
- or Case III. Two qualities each independently enumerated or measured, each quality for one different set of constituent equal sub-areas, each of which set of sub-areas collectively makes up a distinct composite area, provided that regardless of their relative size or orientation the two composite areas thus involved are geometrically similar and homologously subdivided.

**FIND:**

For any given set-up of the above type, a single value, less than one, which measures the degree of resemblance in geographic or geometric distribution of the given quality or qualities among the several constituent sub-areas of the involved composite area or areas.

**THE FORMULA:**

The formula for the Index of Resemblance in Geographic Distribution follows:

$$R = 1 - \sqrt{\frac{\sum \left( \frac{d}{m} \text{ for A} - \frac{d}{m} \text{ for B} \right)^2}{n}}$$

R = Index

d = Datum for particular sub-area

m = Mean of the several data for the particular group of sub-areas

A and B represent the two different qualities measured in the same group of sub-areas, or the two different groups of sub-areas in each of which the same single quality is measured.

n = Number of comparable primary sub-areas, geometrically equal and similar, characteristic of the particular problem

**SIZE AND ORIENTATION**

While the two basic areas may or may not be identical, they must always be geometrically similar and homologously subdivided. When two basic areas are involved neither difference in size nor difference in orientation is a factor. Furthermore, difference in orientation may permit an inverse or mirror-image difference between the two basic areas.

**GEOMETRIC SYMMETRY**

While it is desirable to cover the basic area with a system of grid-squares in perfect geometric fashion, when such geometric grid is impractical, often existing subdivisions approximating symmetry and equality in sub-areas may be used in connection with many pre-existing data for computation of the Index of Resemblance in Geographic Distribution.

**CODIFICATION AND ANALYSIS OF PAN AMERICAN  
IMMIGRATION-CONTROL LAW**

This study was undertaken mainly to determine the immigration policy of each of the several primary political sub-divisions of Pan America, i.e. by the 21 Republics, the 3 quasi-sovereign countries and the 17 European colonies, as a factor in the control of population trends—both qualitatively and quantitatively—of the particular country.

## CODIFICATION

Systematic search is being made through the laws and regulations of each of these 41 countries for statutes, treaties and rules by which the particular country seeks to control human migration, whether voluntary or compulsory, in any manner.

This systematic codification, which is being set up in the languages and texts of their several enactments, and which covers all constitutions, constituent acts, laws, treaties and regulations which pertain to human migration-control in the Western Hemisphere, is preparatory to their systematic analysis for determining for what purpose, in what manner, and to what extent each of the 41 primary political sub-divisions of Pan America exercises sovereign authority in the enactment and execution of its own policy on human migration.

As a matter of classification, in order to give system to the codification, the pertinent laws are presented in the following order:

- I Nation concerned
- II Domestic precedence or supremacy
- III Chronological sequence
- IV Closeness of bearing of the subject of the law upon immigration

*I—Nation concerned*

1. The twenty-one Pan American Republics are treated in alphabetical order.
2. The three Dominions or semi-sovereign countries are treated in the following order: Canada; Newfoundland and Labrador; Iceland.
3. The seventeen European-governed colonies are treated alphabetically within each group possessed by the same European country. Holding countries are treated in the following order: Great Britain; France; Netherlands; Denmark.

*II—Domestic precedence or supremacy*

Within the law of each country the order of precedence or supremacy determines the order of presentation.

1. National Constitution
2. Statute Law enacted by the Legislature—national, provincial, local.
3. International Treaty
4. Administrative Regulation

*III—Chronological sequence*

Within each group of laws relating to the same country and of the same order of precedence, when no order in importance is patent, the chronological sequence is followed.

*IV—Closeness of bearing of the subject of the law upon immigration*

All of the laws and treaties listed and analyzed in the researches herein reported deal basically with human migration considered from the standpoint of the Western Hemisphere. There are among such laws a number of statutes based primarily upon some other subject, but with parts or implications closely related to immigration-control. These laws affect the fundamental biological conditions involved when people move from one

region to another, and therefore their pertinent references must be included in the present study, if herein the legal aspect of immigration into Pan American countries is to be complete.

Within this group of pertinent subjects this sequence is followed:

1. Immigration, and colonization by immigrants
2. Emigration
3. Temporary visitors (passport regulations)
4. Deportation and exile
5. Repatriation and expatriation
6. Extradition
7. Recall and military service
8. Naturalization

#### ANALYSIS

The analysis of the materials thus far codified is under way. This part of the present research covers the items of law and policy in reference to the migration-standards set-up and the authority exercised in their execution by the particular country. The analysis also is making search for any force expressed in law or national policy which the particular country attempts to use to influence the selection and movement of population into and out of its own territory, to influence population-change in numbers, or in racial character, and, within the particular race, either to advance race-improvement or to cause race-degeneracy. The analysis is seeking also the distinctive policies of American countries as immigrant-receiving nations contrasted with the migration-control policies of the emigrant-exporting countries of the Old World, that is, of the countries of Europe and Africa opposite the Atlantic coast, and those of Asia and the Southern Islands opposite the Pacific coast of Pan America. Special attention is being given to the matter of migration-control by treaty, to determine whether there exists any general relation between the completeness of sovereign authority exercised by the immigrant-receiving country and migration-control solely by domestic law or between the limitation of national sovereignty and the control or modification of domestic immigration and emigration policy by international treaty.

In reference to basic purpose, the studies seek particularly to analyze the differences expressed through statute law between migration-control policies as economic matters on the one hand and, on the other, as efforts to improve the human parent-stock for successive generations. In reference to the qualities required of the individual immigrant, the analysis is listing the immigration and emigration standards of each country in reference to numbers admissible and national quotas, to race, religion, age, sex, language spoken, native intelligence, general education, special skill, training or learning, health, sanity, economic condition, political faith or advocacy, criminal record, and family connections.

The analysis is seeking further to determine to what extent there is already a common Pan American migration-control law and policy, as well as making an exposition of the acts and forces exercised in migration-control distinctively by each country, or group of countries, of the New World.

## COORDINATION WITH OTHER RESEARCHES

The present work—the codification and analysis of migration law—fits in well as one of a series of studies contemplated on the re peopling of Pan America since the discovery. In this field the present work ties up with the drawing of the new Pan American Master Map and the working out of the new Indices of Resemblance in Geographic Distribution of Measured Qualities. Other studies, contemplated in collaboration between the Eugenics Record Office of the Carnegie Institution of Washington and the Pan American Union, cover such matters as (a) the statistical records and analysis of immigration into and emigration from the New World by number, race and quality for each human generation since the discovery in 1492, (b) internal migrations within the Western Hemisphere, and (c) the distribution and race-descent character of the Pan American population by generations due to differential mate-selection, to differential fertility, and to differential age-survival.

## COIL-SPRINGS AND CHROMOSOMES

The main results of several years' research on the coil-spring properties of chromosomes were published during the year.

While accepting the principle that there are many chemical, electrical and other factors involved in chromosomal duplication and cell-division, this particular study confined itself to a critical examination of the parallel situations and limitations in the resemblance between coil-springs and chromosomes with particular reference to certain of their common structural, mechanical and chemical attributes. If at definite times in the history of chromosomes, their essential heredity-material exists in the shape of a coil-spring, chromosomes must, of course, during such time obey the rules which Nature imposes upon the relationship and movement of all structures so shaped. The main problem of this particular examination is stated as follows:

If the stuff of a given chromosome is at one time a spireme thread in structure, which at another certain time shrinks in length and curls into a sort of tangle, and ultimately still further into a chromosome, and if the latter seems to duplicate itself exactly, particle by particle, and then to split longitudinally, under what conditions of orientation, twisting and timing could such duplication take place, the resulting chromosomes separate, and each of the two daughter chromosomes be permitted to migrate toward opposite centrosomes or poles?

In order to test certain striking parallelisms in structure and behavior between chromosomes and coil-springs, a number of illustrative experiments were devised wherein wire models were built and manipulated. Given the main chromosomal facts of cell-division, these models show how and why the coil-spring shape really systematizes and aids, instead of tangling and hindering, chromosomal duplication and separation. These mechanical parallels cover the following cases:

1. Flank orientation—complete separation of the two daughter chromosomes.
2. Axial orientation—non-separability of the two daughter chromosomes.
- 3-15. Special cases.

Besides the principle of separability of the two daughter chromosomes, the coil-spring principle was found to be in harmony with and to offer a possible explanation of situations otherwise difficult of understanding in the process of cell-division. One of these explanations covered a special physical difficulty in reproducing chemically and structurally the daughter chromosome from the mother chromosome, when the whole chromosome, as seen under the microscope, appears as a solid-rod with a diameter many hundreds of times that of the inter-facial zone of the particular "gene-molecules." The coil-spring postulate would require the specific organization and reproducing influences of the mother chromosome to extend only a distance within the inter-facial zone of the parent molecules.

#### THE COIL-SPRING POSTULATE

Many of the phenomena which cytologists and geneticists have reported in chromosomes are mechanically, chemically, electrically and mathematically explainable, if, in fact, at the time of duplication and separation the essential heredity-stuff of the chromosome possesses the shape and certain physical properties of a coil-spring.

#### THE MEASURE OF CONSANGUINITY

During the year studies were continued on the measure of consanguinity. By consanguinity is meant commonness-of-blood possessed by two specified individuals. Blood in this sense means inborn constitution or the hereditary stuff or qualities which are transmitted from generation to generation. If individual *a* has more consanguinity with *b* than *a* has with *c* it is, by definition, because *a* and *b* carry by common descent more of the same hereditary qualities than *a* and *c* carry in common. Studies in this field were continued because two basic researches in heredity and eugenics are in need of more definite standards than exist for the designation and measure of commonness-of-blood and for nearness in blood-kinship.

The first of these studies in need of a better kinship-measure is concerned with the measure of resemblance between the propositus and one definitely named near-blood-kin as one piece of evidence in building up the probability-resultant for the prediction of quality or capacity in the offspring. Progress in this field is reported under title, "Additional Manerkonik Cross-sections."

The second and different kind of need for a more definite measure of consanguinity is found in the attempts to achieve a more systematic analysis of the pedigrees of human qualities indexed in the archives of the Eugenics Record Office. A mechanical punch-card system would, if made practically applicable to this problem, greatly facilitate the analysis of pedigree-data, so that all indexed material on human quantities could be analyzed periodically, and thus genetical analysis kept up with accumulated pedigree-data. Assigning one card to each individual in the particular pedigree, the punch-card problem for the archives of the Eugenics Record Office has two aspects:

(a) The individual history and description is satisfactorily solved

(b) The pedigree-position-listing is not yet solved, but it is believed that ultimately it will be possible to devise a mechanical punch-card for the systematic analysis of human pedigrees by blood-kinship.

## THE MEASURE OF CONSANGUINITY BY COMMON-CARRIED CHROMOSOMES

Preliminary to further attack on the problem of mechanical analysis of the pedigree network, two types of measure-of-consanguinity or commonness-of-blood have been worked out. The first is based on the zygotic-chromosome-formula for the particular species. For example, in man the zygotic formula for the human female is  $(23 + 1X) + (23 + 1X)$ . The corresponding formula for the human male is  $(23 + 1X) + (23 + 1Y)$ . The measure of commonness-of-blood, or hereditary qualities, when based on the number of zygotic chromosomes carried in common, depends upon the mathematical probability of the propositus or central figure carrying in his or her 48 somatic chromosomes a definite number of chromosomes which are duplicates by meiotic division and descent with those carried in the zygote of the individual near-kin whose consanguinity with the propositus is being measured.

## THE MEASURE OF CONSANGUINITY BY DICHOTOMOUS DESCENT

More like its use in common law than ordinarily in biology, the second type of measure of consanguinity is based upon the addition of values of chains of common descent through bi-sexual heredity. Thus if one seeks to determine the amount of common blood carried by the subject or the propositus on the one hand and some definitely named near-blood-kin on the other—

*First*, one uses as the yard-stick or unit of measure the "parent-child relationship," and by the rules of biology, of common law and of good judgment assigns the "kinship fraction  $1/2$ " to this, the elementary link in blood-relationship.

*Second*, one traces the specific blood-kinship by the "shortest chain possible" between the two kin, always using the "parent-child yardstick" as the unit-link and always assigning the consanguinity value  $1/2$  to each such link in the chain, and always "multiplying successively values of the several unit-links" to determine the consanguinity value of the particular chain. Thus the consanguinity-value of a given kinship-chain equals  $(1/2)^n$ , in which  $n$  = least number of links possible in the particular chain.

*Third*, one computes the total measure of consanguinity between the two specified kin by adding together the specific values thus determined for each of the several individual chain-values.

Thus, barring inbreeding, the brother-sister kinship equals a consanguinity value of  $1/2$  or  $(1/2 \times 1/2) + (1/2 \times 1/2) = 1/2$

In this particular kinship let the brother represent the propositus,  
 then the propositus-father kinship =  $1/2$   
 the father-daughter kinship =  $1/2$   
 $1/2 \times 1/2 = 1/4$  = the value of the  
 propositus-sister kinship through the father.

The propositus-mother kinship =  $1/2$   
 the mother-daughter kinship =  $1/2$   
 $1/2 \times 1/2 = 1/4$  = the value of the  
 propositus-sister kinship through the mother.  
 $1/4 \times 1/4 = 1/2$  = the summation of all consanguinity-values of the  
 brother-sister kinship.



The measure of consanguinity is thus important as a standard for reference and comparison preliminary to either Mendelian or manerkonic analysis.

In successful manerkonic analysis such questions as the following can be answered—

If the sire-foal measure of consanguinity be correctly represented by the fraction  $\frac{1}{2}$ , and the dam-foal resemblance be similarly represented by the fraction  $\frac{1}{2}$ , in one thousand instances, all other factors being randomly represented, how does the sire-foal resemblance in racing capacity differ both quantitatively and qualitatively from that of the dam-foal?

Again, in the long run, how do each of the four grand-foals differ in their respective racing-capacity resemblances to the foal?

Or, how does a full brother, which has a consanguinity of  $\frac{1}{2}$  with the propositus or foal, differ in racing-capacity resemblance from the sire-foal resemblance which also is measured by a  $\frac{1}{2}$  consanguinity-value?

Or, how does a half-brother, which carries  $\frac{1}{4}$  common blood with the foal, differ in racing-capacity resemblance from a grandchild, or from an uncle, each of which carries the same amount, i.e.  $\frac{1}{4}$  common blood with the foal?

Thus is seen the need for a reliable measure of consanguinity as a tool in genetic analysis.

#### ADDITIONAL MANERKONIC ANALYSES OF RACING CAPACITY IN THE THOROUGHBRED HORSE

Further progress has been made in the analysis of racing capacity in the thoroughbred running horse, and in the determination of the rules by which nature governs the inheritance of this quality. The specific researches of the year bring the number of completed manerkonic analyses in this field to ten. Each such analysis represents one definite kinship, is based upon the measured racing capacities in at least 1000 foals and their specified kin, and, for the particular kinship, has determined the specific values of the function  $K = f(M, R)$  in which  $M$  is the prediction-basis or the racing capacity actually developed by the particular near-kin of the foal.  $R$  is the thing-predicted or the racing capacity developed by the foal, and  $K$  is the probability which measures the resemblance in racing capacity between the foal and the definitely selected kin, all other factors being randomly represented. Each manerkonic analysis thus represents, for a particular kinship, a piece of independent evidence in racing-capacity-prediction when such prediction is based upon the probability-resultant of several such pieces of independent evidence, each from a selected near-blood-kinship.

The following outline of the manerkonic analysis of the sire-foal resemblance in racing capacity is typical of each manerkonic study:

##### THE SPECIFIC MANERKONIC FORMULA FOR THE SIRE-FOAL RELATIONSHIP

As a result of the analysis of the measured racing capacity values of 1009 foals from 219 different sires it is concluded that for the sire-foal resemblance in racing capacity as an independent factor, all other major factors in the development of racing capacity in the foal being randomly represented—

$$K = f(M, R)$$

$$K = K_{fc} - \frac{(FC - R)^2}{2(\sigma_{\text{left or right}})^2}$$

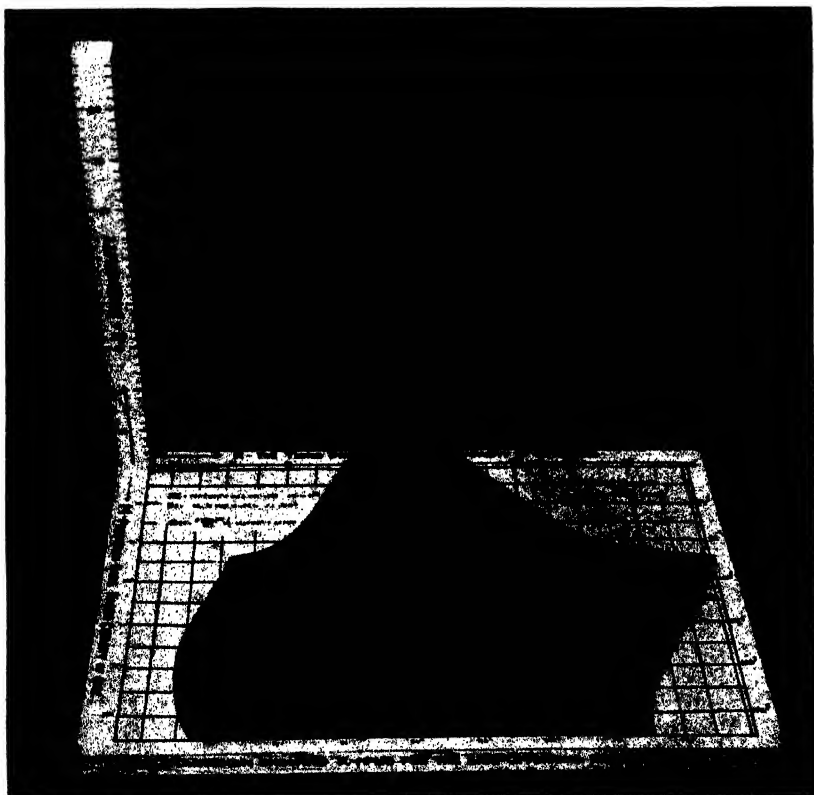
$$FC = f(M) = -956.49763 + 26.314667M - 0.214735M^2 + 0.000579908M^3$$

$$K_{fc} = f(M) = 0.27706 - 0.0027108M + 0.000014254M^2$$

$$\sigma_{\text{left of FC}} = f(M) = 134.170138 - 3.416097M + 0.03293285M^2 - 0.000105886M^3$$

$$\sigma_s = \frac{1.9997}{K_{fc}} \quad \text{"s" represents } \sigma \text{ symmetrical i.e. in case of no skewness}$$

$$\sigma_{\text{right of FC}} = \frac{3.9894}{K_{fc}} - \sigma_{\text{left}}$$



Sire-Foal Resemblance in Racing Capacity  $K = f(M, R)$

Built on the same mathematical pattern, but modified to the specific values, a similar manerkon is being built for each of the fourteen independent near-blood-kinships included in the immediate researches. When the several M-or-prediction-bases are independent for each of the several manerkons, a transverse cross-section of one manerkon at the selected M-value constitutes the piece of independent prediction-evidence used in the computation of the probability-resultant. Other things being equal, good prediction is indicated by a tall narrow manerkon in which the saddle-axis shows substantial diagonalness in moving from high to low M-values. Conversely a low, wide-spreading manerkon with a straight fore-and-aft M-axis means relatively poor prediction.

TABLE OF K OR PROBABILITY-VALUES

For each completed manerkonic analysis a table has been computed from the specific formula which gives the K or probability-values for the predicted racing-capacity value in the foal for each possible 5-pound class-range—that is, for each class-range of  $R \pm 2.5$ , based upon each pound-difference of racing capacity in that particular kinship which represents the prediction-basis or M, in the specific formula  $K = f(M, R)$ .

These cross-section values thus tabulated are the elements which the geneticist and the breeder use as units in the computation of the probability-resultant of racing capacity in the offspring, based upon the capacity actually developed by each of the several blood-kin used in the particular computation, all other major factors being randomly represented.

During the year there was completed a 4-page folder entitled "Work-sheet for the Computation of the Hereditary Racing Capacity of the Foal as the Probability-resultant of the Combined Influence of Measured Racing Capacity in each of the Several Near-blood-kin."

This work-sheet provides for the use of manerkonic cross-sections as prediction-elements, that is, of pieces of independent evidence, covering the racing capacities of near-blood-kin as follows:

1, Sire; 2, Dam; 3, Sire's Sire; 4, Sire's Dam; 5, Dam's Sire; 6, Dam's Dam; 7, Full Sib; 8, Half Sib (with common sire); 9, Half Sib (with common dam); 10, Child ( $F_1$  offspring); 11, Grandchild ( $F_2$  offspring); 12, Uncle or Aunt; 13, Nephew or Niece; and 14, First Cousin.

The first six of these manerkonic analyses are specialized by elementary or basic kinship and sex, but the subsequent eight manerkons are generalized to cover type-of-kinship regardless of sex. While not listed on the "work-sheet," there has been completed also a manerkonic analysis in which M, or the prediction-basis, is an index in which the racing capacity of the sire and of the dam are arbitrarily stressed 50-50.

While it would be highly desirable to prepare a manerkonic analysis for each near-blood-kinship which carries  $\frac{1}{8}$  or more of common blood with the propositus or foal, such computation, not involving the factor of inbreeding, would require the preparation of sixty-eight manerkons for the male foals and sixty-eight more for the female foals. Thus on account of the amount of work involved in the longer but more desirable investigation, the present researches on the inheritance of racing capacity in the Thoroughbred horse have for their immediate goal the foregoing list of fifteen manerkonic analyses.

## ANTHROPOLOGY AND HUMAN GENETICS

*Morris Steggerda and Harriet Cranston*

## GROWTH IN CHILDREN OF DIFFERENT RACES

Four hundred forty children, belonging to the Negro, White, Navajo, and Maya races have been measured for at least four successive years. On each child a series of forty-six physical observations was made each year. This will form the material for future investigations on the comparative growth of children of different races. Last year a Height and Weight chart was made from these data for Navajo children and during the current year a similar chart was made for the Dutch white children in Michigan. These charts are based upon a much larger number of cases than that which comprises our growing series. The advantage of these Height and Weight charts is that they are made from homogeneous groups and are thus more applicable for those groups than are the charts made from the combined records of white children from various racial groups throughout the United States. It was found that the weights of Navajo boys of a given height are lower than those of Dutch white boys of all ages. This is true of all girls up to 13 years of age; after 13 years the Navajo girls are heavier than White girls. It was found also that the predicted weights for specific heights in the tables for both Navajos and Whites are lower than those in a popular type table based on measurements of American children in general, prepared by Mead and Johnson. This emphasizes the need of such charts for homogeneous groups.

## THE INCIDENCE OF DENTAL CARIES IN HUMAN STOCKS

Based on the examination of approximately 5000 mouths of individuals belonging to the Maya, Navajo, Dutch White and Negro races, the accompanying table was compiled. It will be noted that the Mayas and Navajos have much better teeth than do the Negroes and Whites. For example, in

*Tooth Decay in Various Races*

Age	DUTCH (White)				MAYA (Indian)				NAVAJO (Indian)				JAMAICA (Colored)			
	Number examined	% having caries	% of carious teeth	Average cavities per person having caries	Number examined	% having caries	% of carious teeth	Average cavities per person having caries	Number examined	% having caries	% of carious teeth	Average cavities per person having caries	Number examined	% having caries	% of carious teeth	Average cavities per person having caries
6-10 . . .	702	46.9	4.2	2.4	375	3.2	0.3	1.8	647	5.3	0.3	1.6	...	...	...	...
11-15 . . .	533	88.2	12.8	4.3	319	10.7	1.9	1.5	634	17.0	1.0	1.7	304	69.4	10.2	4.1
16-20 . . .	123	96.7	24.1	6.9	106	37.7	2.5	2.6	491	32.6	3.3	2.8	144	71.5	18.6	7.2
21-25 . . .	...	...	...	...	76	60.5	6.1	3.3	60	58.3	7.4	3.5	86	80.2	24.0	8.4
26-30 . . .	...	...	...	...	43	65.1	7.2	3.7	21	66.7	7.0	3.2	44	90.9	26.6	9.4
30-35 . . .	...	...	...	...	25	72.0	8.9	4.4	8	50.0	9.4	6.4	21	95.2	28.3	9.0

the 16 to 20 age group, 97 per cent of the Dutch Whites examined had some decayed teeth, while only 38 and 33 per cent of the Mayas and Navajos, respectively, had decayed teeth. The Negroes were intermediate, 72 per cent having some decayed teeth. The same differences are seen in the percentage of carious teeth and the average number of teeth cavities per person having any decay.

The fact that the two Indian groups have such excellent teeth is of peculiar interest since one group (Maya) are carbohydrate eaters and the other (Navajo) are protein eaters. Carbohydrates, according to one school of dental investigators, cause *Bacillus acidophilus* to flourish in the mouth. This is the bacterium which produces the acid which disintegrates the tooth, causing decay. Furthermore, neither of the Indian groups brush their teeth consistently, which is also essential to sound teeth according to some dentists. In the analysis of this material we have proposed that heredity be considered as a causal factor in producing good teeth.

#### FOOD OF THE MAYA

During the past several years we have been cooperating with Dr. F. G. Benedict of the Nutrition Laboratory on the problem of the food of the Maya Indians. The work is now completed and we can say that on the average 73 per cent of the daily energy intake of the Maya comes from maize. This intake averages 2565 total calories, which is 26.71 per cent lower than that of the average American laborer. The problem of the food of the Maya was undertaken partly to determine if their food consumption would explain the previously found fact that their basal metabolism averaged 8 per cent higher than the White standards. It was concluded from the food study that the food of the Maya could not explain the high metabolism.

#### MENTAL CHARACTERISTICS OF RACES

The McAdory Art Appreciation Test was given to 300 Navajo Indian children and the results compared with norms made upon White children. These results were in every case lower than the norms. It is generally conceded that the Navajo Indians are artistically inclined, as is evidenced by their rug designs, jewelry, and pottery making. Thus it must be said that the McAdory Art Test in its present form, based as it is on White man's culture, does not reveal the artistic capacity of the Navajos. A test is now being designed by us based upon articles from Navajo culture. It is planned to standardize the test on Navajos and then in turn give it to a similar group of Whites.

By the use of the Goodenough Drawing Scale, in which the child merely draws a man from memory, as a measure of performance, it was found that the Navajo children for the years 10, 11, and 12 did considerably better than white children of the same ages, upon whom the test was standardized. The Maya Indians, on the other hand, did very poorly as compared with the norms. These results fit in with the general idea of the artistic capacity of the Navajos. Additional material is being gathered for the lower ages of the Navajos.

The Gesell Schedules were given to 1-, 2-, and 3-year old Negro children in Jamaica in 1928, and only this year were the results analyzed, with the

cooperation of Dr. M. W. Curti of Smith College. The results of this study are as follows: the Jamaica children when compared with New Haven children are precocious in age of creeping, standing, and walking, and are superior to the New Haven children in running errands and equal them in other practical activities, but are markedly inferior in certain personal social items, such as the use of spoons in eating and in the understanding of numbers.

This year an attempt was made to transcribe the Minnesota Pre-School Scale into Maya, and objects familiar to the Indians of Yucatan were used. It is expected that results along this line will be available in another year.

For several years we have attempted to give to the Indians tests, designed chiefly by Dr. A. F. Blakeslee, to determine the threshold of taste. The problem has now become chiefly psychological, since the Navajos are exceedingly stoical when it comes to expressing their taste reactions. They are far more stolid and inexpressive than the Maya Indians, Negroes, or Whites. This stolidity may have two interpretations. Either the Navajo may taste the impregnated paper but is able to control his feelings and give no hint of the taste he is experiencing; or his taste may be so dull that he is not aware of his own threshold of taste. Thus it becomes exceedingly difficult to interpret the results of this test.

NUTRITION LABORATORY<sup>1</sup>

FRANCIS G. BENEDICT, DIRECTOR

With the approach of retirement the scientific activities of the Director have been planned carefully for many years back. The two major divisions of activity are experimental and literary. The experimental work ceased June 30, 1936. From the inception of the Nutrition Laboratory a large proportion of its activities has of necessity been directed toward the development of techniques imperatively needed in the attack on nutritional problems, for which the Laboratory was planned. Agricultural chemistry has from its earliest days been more or less on the defensive, but in such a laboratory as that of Professor E. G. Ritzman at the University of New Hampshire, at Durham, one finds nutritional problems attacked with the same meticulous care and the same nicety of manipulation as are employed in studies of the most abstract chemical problems. Because of the excessive caution taken to perfect every step and every side issue of a study, the techniques used in nutrition investigations were at the start extremely complicated, almost unwieldy, and possible only in such a specially subsidized laboratory as the Nutrition Laboratory. In the last decade the moral obligation to simplify technique in order to make it widely feasible has urged us strongly, and whereas the first decade after the establishment of the Nutrition Laboratory was devoted to the elaboration of ultra-refinements—refinements necessary in establishing standards—now we may safely simplify the experimental procedures and rely upon the mass of standard data that has been accumulated to confirm procedures. In 1910 basal metabolism measurements could be made only in special laboratories. Today there are instruments in no less than fifteen thousand physicians' offices, laboratories, and hospitals where such data can be readily and accurately secured. Further simplification is still in the experimental stage, but as was announced in last year's report, a respiration apparatus enabling metabolism measurements on a direct-reading instrument is now available. Thus the extremely complicated respiration calorimeters with which nutritional problems were studied in the first decade of the Nutrition Laboratory's existence are rarely used today, as much of the most important data can be secured with modern, simplified methods. This experimental service of the Laboratory terminates, under the guidance of the present Director, with the completion of portable, simple respiration apparatus that put basal metabolism measurements on the same basis as most of the measurements necessary for a physiological survey and physical examination of hospital patients. Basal metabolism measurements are becoming more and more the custom, and ultimately will be the general practise in yearly health examinations.

In pathology the need for more elaborate apparatus will be felt for a long time, as the careful clinician may no longer be satisfied solely with the measurement of the basal metabolism. This quantitative index of the intensity of vital activity must be supplemented, in the diagnosis and treatment of many pathological cases, by a knowledge of the character of

<sup>1</sup> Situated in Boston, Massachusetts.

the material burned in the body, with special reference to carbohydrate combustion. Hence knowledge of the respiratory quotient, that is, the relationship between the volume of carbon dioxide exhaled and the volume of oxygen absorbed, is becoming continually of increasing importance. For this determination a simple apparatus is not available and there is no reasonable prospect of one being immediately developed. The skill of the expert gas analyst, using preferably the Carpenter gas-analysis apparatus, alone will give these frequently much desired data.

### COOPERATING AND VISITING INVESTIGATORS

Dr. Edward H. Bensley, of the Department of Metabolism, Montreal General Hospital, Montreal, Canada, has spent the past year at the Nutrition Laboratory in the study of our experimental techniques and has cooperated with Dr. T. M. Carpenter in investigations of the effects of ingestion of sugars upon human heat production, respiratory exchange, alveolar air, and blood lactic acid. In a portion of these researches they have enjoyed the cooperation of Dr. D. B. Dill and Mr. H. T. Edwards, of the Fatigue Laboratory of the Harvard School of Business Administration.

Dr. Milton O. Lee, of the Memorial Foundation for Neuro-Endocrine Research at the Harvard Medical School, has continued his cooperation in the study of the effect of thyroidectomy on the metabolism of geese.

Dr. Howard F. Root, of the New England Deaconess Hospital, Boston, is cooperating in a study of the metabolism in diabetic coma, and Dr. Priscilla White of the same hospital has cooperated in a study of a helium-oxygen mixture for prevention of respiratory failure in new-born infants of diabetic mothers.

Dr. Alvan L. Barach, of the Presbyterian Hospital, New York City, is cooperating with the Nutrition Laboratory in the use of the helmet-rotamesser respiration apparatus for the relief of dyspnea by use of a helium-oxygen mixture.

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, has continued his cooperative investigation with the Nutrition Laboratory, laying special emphasis upon the metabolism of horses, bulls, dairy cows during lactation, sheep, and pigs.

Dr. George L. Streeter, Director of the Department of Embryology at Baltimore, has continued his support of the study of the *Macacus rhesus*, in association with Dr. T. M. Carpenter of the Nutrition Laboratory and Dr. C. G. Hartman of Baltimore.

Professor H. C. Sherman, of the Department of Chemistry at Columbia University, retained an active interest in the cooperative investigation on the effects of old age and exercise upon the metabolism of the rat.

Professor Carey D. Miller, of the Department of Household Science of the University of Hawaii in Honolulu, brought to an end in September 1935 her observations on the metabolism of various races in Hawaii and the Polynesian natives of Samoa.

Dean Stanley D. Wilson, of the College of Natural Sciences, Yenching University, Peiping, China, has terminated his cooperative research with



the Nutrition Laboratory, and the results are now being summarized in suitable tabular form for analysis, preparatory to the writing of a report.

One of the Carnegie Institution of Washington's annual Biological Conferences was held on January 11, 1936, at the Laboratory for Animal Nutrition, University of New Hampshire, Durham, New Hampshire. Members of the Carnegie Institution of Washington who were present were Messrs. F. G. Benedict, A. F. Blakeslee, T. M. Carpenter, W. M. Gilbert, C. G. Hartman, R. C. Lee, E. C. MacDowell, O. Riddle, and G. L. Streeter. In addition, Dr. Milton O. Lee and Professor George B. Wislocki of the Harvard Medical School were in attendance. Members of the Laboratory for Animal Nutrition at Durham who were present were Professor E. G. Ritzman and N. F. Colovos. President E. M. Lewis of the University of New Hampshire and Director J. C. Kendall of the Agricultural Experiment Station entertained the group at luncheon. Following the conference at Durham, the group returned to Boston and continued scientific presentations and discussions at the Nutrition Laboratory.

### LECTURES

On March 25, 1936, a paper on "Parallel determinations of human alveolar carbon dioxide and respiratory quotient after ingestion of galactose" was given by Dr. T. M. Carpenter at the Third Annual Meeting of the American Institute of Nutrition at Washington, D. C. On April 25 Dr. Carpenter lectured to the students in the course in Biochemistry at the Harvard Medical School on "Basal metabolism and specific dynamic action."

Lectures on the physiology of the elephant, illustrated with lantern slides, were given by the Director as follows: On January 14, 1936, before the Harvard Medical Society at the Peter Bent Brigham Hospital in Boston; on February 10 at the Journal Club meeting of the Department of Genetics of the Carnegie Institution of Washington at Cold Spring Harbor, Long Island, New York; on February 13 before the Graduate Science Club of the University of New Hampshire, at Durham, New Hampshire; on February 20 before the Thursday Evening Club in Boston; on April 14 in the Department of Physiology and Biochemistry at Cornell University Medical College, Ithaca, New York; on April 21 as a "University Lecture" at Yale University, New Haven, Connecticut; and on April 22 in the Department of Physiology, New York University College of Medicine, New York City.

### INVESTIGATIONS IN PROGRESS

*Metabolism studies on the Macacus rhesus*—The metabolism measurements on the *Macacus rhesus* have been continued. During the past year measurements have been made on a number of animals, including a young male, after 24 hours of exposure to low environmental temperature (11° to 18° C.). The effect of 48 hours' sojourn at 28° C. during the cold months was also measured on two animals. The rectal temperatures before and after the observations on metabolism are now regularly taken. The investigation has been carried on by Dr. T. M. Carpenter, with the cooperation of Dr. George L. Streeter and Dr. Carl G. Hartman, and with

the technical assistance of K. Koudelka, of the Department of Embryology at Baltimore.

*Comparison of direct and indirect calorimetry with man after the ingestion of hexoses*—The heat elimination of a human subject after the ingestion of 50 and 100 grams of glucose, fructose, or galactose has been directly determined with the emission calorimeter. Simultaneously measurements were made of the respiratory exchange by means of the open-circuit principle and gas analysis, and of the water-vapor output. Periodic determinations of the rectal temperature and of the skin temperature at three points accompanied the other measurements. The experiments were carried out by Dr. Carpenter with the cooperation of Dr. Edward H. Bensley of the Montreal General Hospital, and with the technical assistance of V. Coropatchinsky, B. James, and Miss Anna J. Murphy.

*The respiratory exchange, alveolar air, and blood lactic acid of man after the ingestion of hexoses*—A further investigation as to the causes of the differences in the changes in the respiratory quotient of man after the ingestion of hexoses has been made by determining the respiratory exchange, alveolar air, and the lactic-acid content of the blood periodically, with two subjects after the ingestion of glucose, fructose, and galactose. The study has been made by Dr. Carpenter with the cooperation of Dr. Edward H. Bensley of the Montreal General Hospital, and of Dr. D. B. Dill and Mr. H. T. Edwards of the Fatigue Laboratory of the Harvard School of Business Administration. The respiratory exchange and alveolar air determinations were made with the assistance of B. James and Miss Anna J. Murphy.

*Metabolism in diabetic coma*—Dr. Carpenter is cooperating with Dr. Howard F. Root of the New England Deaconess Hospital in making basal metabolism measurements on patients in diabetic coma. The object of these determinations is to obtain data that may be useful in the diagnosis and treatment of this disease. The apparatus used for these tests has been the portable helmet respiration apparatus devised at the Nutrition Laboratory. This is the only type of apparatus that lends itself to these studies, as the patient when in coma can not cooperate with the one making the observations, and it would be impossible to measure the metabolism with the common clinical respiration apparatus employing the mouthpiece. In these measurements Dr. Carpenter has been assisted by R. C. Lee and B. James.

*Observations on the elephant*—Supplementing the metabolism measurements and other physiological observations on elephants, begun in the spring of 1935, a careful study was made of the chewing and drinking habits of this animal, to throw light on the efficiency of its digestive system and the use of its teeth in mastication. Other data were obtained on the skin temperature, the respiration rate, the sleeping habits, and the composition of expired air, with particular reference to the methane content which serves as a guide to estimate the fermentation processes in the digestive tract. The heart rates of 37 elephants were established. These measurements were carried out by the Director, assisted by R. C. Lee, in large part at the winter quarters of the Ringling Brothers-Barnum & Bailey

Circus, located at Sarasota, Florida. The Nutrition Laboratory is very grateful to Mr. S. W. Gumpertz, Manager of the Ringling Brothers Circus, to Mr. Edward Doherty at that time in charge of the elephant herd, and likewise to the present head elephant man, Mr. Lawrence Davis, for their courtesy and assistance in making these measurements possible. With the volunteer assistance of Mr. J. L. Jenks jr., of the Sanborn Company, Cambridge, Massachusetts, electrocardiograms were secured with ten elephants of the Ringling Brothers herd, on May 3 to 9, 1936.

*Metabolism of the woodchuck*—In continuance of the investigation on the woodchuck, which has been in progress for several years, studies have been made of the heat production of this animal when hibernating, its metabolism in the zone of thermic neutrality when non-hibernating, its metabolic reaction to cold when awake, and its body temperature. Data have also been secured on the heart rate and the respiration rate during hibernation, the body weight, the length of life during fasting, the insensible perspiration, and the fat content of the body at death resulting from fasting. The observations have been made by R. C. Lee, assisted by G. Lee and C. Hatch.

*Physiology of different races of mice*—To establish the basal heat production of the smallest mammal available, the Nutrition Laboratory has continued its study of various races of mice, the white, the wild, and the dwarf, the latter having been contributed by Dr. E. C. MacDowell of the Department of Genetics, who generously supplied the fat mice used in an earlier research. Information regarding the physiology of this smallest of available mammals is desirable for comparison with other animal species of greatly differing sizes, and for consideration of the effect upon metabolism of extremes in adult size within the mouse species itself. Furthermore, as the mouse tends to become easily semi-poikilothermic, information regarding its metabolism might help to bridge the gap in our knowledge of the physiology of cold- and warm-blooded animals. The factors studied with these four races of mice have been their basal heat production, their metabolic reaction to high and low environmental temperatures, their body temperature, the effect of prolonged fasting, the water-vapor output, the insensible perspiration, and the chemical composition of the body. The research has been carried to completion with the cooperation of R. C. Lee, assisted by G. Lee and C. Hatch.

*Metabolism of the rabbit*—To contribute further to the interspecific study of the metabolism of animals of various sizes and also to the study of the metabolic effect of size *per se* within one and the same animal species, the Nutrition Laboratory has made additional observations on the basal metabolism of the rabbit. Some of these animals were kindly loaned to us by Professor W. E. Castle, of the Bussey Institution. It is possible in this species to obtain adult rabbits of the same configuration and approximately the same degree of protective fur covering, but with wide variations in body weight ranging from 1.5 kg. in the case of the Polish rabbit to 4 or 5 kg. with the New Zealand Whites. The conditions prerequisite for basal metabolism measurements on the rabbit, with particular reference to the length of fasting necessary and the zone of thermic neutrality, the meta-

bolic reaction to different environmental temperatures, and the normal body temperature of these animals have been special topics of research. R. C. Lee has been in charge of the observations, assisted by G. Lee and C. Hatch.

*Metabolism of thyroidectomized geese*—During the past year the study of avian thyroidectomy has been completed by R. C. Lee, with the cooperation of Dr. Milton O. Lee of the Harvard Medical School, who is now preparing a report of the results for publication.

*Metabolism of the rat*—The research carried out at Columbia University with the cooperation of Professor H. C. Sherman, on the effects of exercise and old age upon the metabolism of the rat, has been terminated. The metabolism measurements were made by Miss A. Zmachinsky.

*Metabolism of large domestic animals*—The unusually profitable cooperative research with Professor E. G. Ritzman, at the University of New Hampshire, Durham, has continued with unabated activity, with special reference to measurements on the horse, five adult bulls, and lactating dairy cows. As a part of a larger program of studies with the horse, in which it is eventually planned to measure the metabolism of the horse in action, a treadmill is now being designed for installation in a large respiration chamber especially built for this purpose. A thoroughbred stallion (Sun God II), which had a very successful turf record both in this country and previously in France, and also a purebred Percheron stallion, which has won championships at the Eastern States Exposition, were studied. The very large respiration chamber for the horse, stallion, and bull was constructed upon principles developed in the elephant research, a fact that illustrates how studies with one animal frequently make direct contributions to studies with others. In these researches Professor Ritzman has been assisted by Mrs. H. H. Latimer and Messrs. N. F. Colovos, A. D. Littlehale, and R. Doe.

*Stack apparatus*—A form of basal metabolism apparatus for humans has been developed, the chief feature of which is a simple container (a pipe stack) of constant volume for the collection of expired air. Expired air, introduced into the bottom of the stack, does not mix with the outdoor air with which the stack has previously been filled, but stratifies itself below it, because of its greater density and because of the mechanical construction of the apparatus. As expired air enters at the base of the stack, air is pushed out of the stack through an exit at the top. Thus it is possible to collect the expired air in the base of the stack without loss, for a 10-minute period. At the end of the collection the air in the stack is thoroughly mixed, and the resulting mixture of outdoor air and expired air is analyzed on the Haldane apparatus. Its accuracy has been demonstrated by measuring the carbon dioxide produced in the burning of a known amount of alcohol. Because of the inexpensive construction of this apparatus, it is conceivable that it will be feasible to use it for student instruction and also in clinics. The apparatus is particularly adapted to studies of the respiratory quotient when the Haldane apparatus is used for the gas analyses. V. Coropatchinsky aided in the construction of the apparatus, and R. C. Lee in the experiments made with it.

*Age and human basal metabolism*—Several experiments have been made by R. C. Lee with individuals whose metabolism has been measured yearly over a considerable period of years, to contribute to the study of the effect of advancing age.

*Oxygen therapy*—During the past year the Nutrition Laboratory has made available to Dr. Alvan L. Barach of the Presbyterian Hospital, New York City, one of its portable helmet respiration apparatus. This has been used in administering oxygen or a mixture of helium and oxygen, when oxygen therapy has been found advisable. The apparatus has proved satisfactory for the relief of dyspnea and can be used in the home of the patient.

*Prevention of respiratory failure in new-born infants*—Another respiratory disorder in the treatment of which the Nutrition Laboratory has rendered assistance is the respiratory failure of new-born infants, especially the infants of diabetic mothers. Frequently such infants become cyanotic within the first 24 hours after birth. To overcome this condition the Nutrition Laboratory, under the guidance of Dr. Priscilla White of the New England Deaconess Hospital, devised a respiration chamber for the administration of a mixture of oxygen and helium, usually 75 per cent helium and 25 per cent oxygen. As helium is an inert gas, it is impossible to determine the helium content of a gaseous mixture by the ordinary absorption method used for the determination of gases. A simple form of densimometer has, therefore, been developed, which has proved accurate for determination of the percentages of helium in gaseous mixtures. One of these densimometers designed by the Nutrition Laboratory has been made available to Dr. Barach, to whom we are greatly indebted for stimulation in our attempts to use helium. In the development and testing of this respiration apparatus much aid was had from R. C. Lee. The instrumental features were constructed by V. Coropatchinsky.

#### EDITORIAL AND LITERARY WORK

Much of the year has been spent in the preparation for publication and in the correction of the proofs of the monograph on "The physiology of the elephant." (See page 79.) In addition, several articles have been written and either have been submitted for publication or are ready to be submitted. These are:

Respiratory metabolism of the chimpanzee. (J. M. Bruhn and F. G. Benedict.)

La production de chaleur de plusieurs races de souris. (F. G. Benedict and R. C. Lee.)

The basal metabolic rate of Chinese in Szechwan. (L. G. Kilborn and F. G. Benedict.)

The basal metabolism of the Miao race of Kweichow. (L. G. Kilborn and F. G. Benedict.)

Comparison of the basal metabolism of the Chinese in Szechwan during waking and sleeping states. (L. G. Kilborn and F. G. Benedict.)

Basal metabolism of normal young men and women of various races in Hawaii. (C. D. Miller and F. G. Benedict.)

Basal metabolism of Samoan men. (C. D. Miller and F. G. Benedict.)

Miss Antoinette Vuilleumier was responsible for the careful translation into French of the manuscript on the heat production of mice. Dr. Blanche B. Daly has continued her association with the Nutrition Laboratory as *littérateur* and in the classification and analysis of a large accumulation of human skin temperature data. The large mass of editorial work has had the critical supervision of the editor, Miss Elsie A. Wilson.

### PUBLICATIONS

- (1) *A chemical hygrometer*. Thorne M. Carpenter. Jour. Biol. Chem., vol. 112, pages 123-133 (1935).

A transportable and commercially easily reproduced apparatus for the determination, by volume, of water vapor in air is described. It is constructed on the principle of a gas-analysis apparatus, in that the volumes of the air sample before and after removal of water vapor by an absorbent are read against a constant volume of air kept dry by phosphorus pentoxide. Comparisons with results obtained by weighing the water vapor absorbed from air currents containing from 0.3 to 2.2 per cent of water vapor showed an average agreement of under 0.02 per cent.

- (2) *Parallel determinations of human alveolar carbon dioxide and respiratory quotient after ingestion of galactose*. Thorne M. Carpenter. Jour. Nutrition, vol. 11, Supplement, pages 7-8 (1936).

An abstract. (See page 72.)

- (3) *Basal metabolism and urinary nitrogen excretion of Oriental women*. Abby H. Turner and Francis G. Benedict. Amer. Jour. Physiol., vol. 113, pages 291-295 (1935).

The basal metabolism of ten well-nourished, foreign-born Chinese, Japanese, Korean, and South Indian women students was lower than that of six American college mates and, on the average, 12 per cent below the Harris-Benedict prediction standards for American women. The Orientals had been living for from one to three years in the United States, in an American college environment and partaking of an American college diet. Comparison of the urinary nitrogen excretion of five of these Orientals and five of their American college mates (living in the same college dormitory and eating at the same table) shows that the Orientals were not partaking of an abnormally low protein diet and that their low metabolic level can not be ascribed to a low protein metabolism.

- (4) *The basal metabolism of male Chinese in Manchuria*. Francis G. Benedict and H. S. D. Garven. Chinese Jour. Physiol., vol. 10, pages 141-147 (1936).

Metabolism measurements under the prerequisite basal conditions were made on twenty northern Chinese males in Moukden, ranging in age from 16 to 36 years (average, 24 years), of an average weight of 54.1 kg., and an average height of 168 cm. Although the majority of the subjects were studied on one day only, the data suggest that the basal metabolism of these northern Chinese is definitely below that of Caucasian males of similar ages, weights, and heights.

- (5) *The food of the present-day Maya Indians of Yucatan*. Francis G. Benedict and Morris Steggerda. Carnegie Inst. Wash. Pub. No. 456, 1936, pages 155-186.

A qualitative and quantitative study was made of the present-day Maya diet in the Chichen Itza region of Yucatan. The foods most commonly eaten and the methods of their preparation for consumption are described.

The daily energy intake averaged 2565 calories per individual, which is low when compared with that of the average American laborer. Of this daily energy intake 73 per cent was derived from maize. The daily protein intake averaged 74 grams per individual, a low rather than high intake. Measurements of the basal heat production of some of these Indians showed that their energy intake was only 66 per cent above their basal needs. This suggests that the muscular effort engaged in by the Maya is not excessive. The fact that the basal metabolism of the Maya averages 8 per cent higher than the standards for white men can not be explained by a protein-rich diet, by an excessive calorie diet, or the after-effect of severe muscular exercise. Hence their high basal metabolism must be ascribed either to an environmental or more probably a racial factor.

- (6) *The heat production of the sheep and the pig before and after castration.* Ernest G. Ritzman, Nicholas F. Colovos, and Francis G. Benedict. Univ. New Hampshire, Agric. Expt. Sta., Tech. Bull. 64, 1936. 24 pages.

The effect of castration upon the respiratory metabolism, heart rate, body temperature, body weight, and general activity was studied with eleven male sheep (five of which served as controls), and one male pig. One of the sheep was a year old at the time of castration. The other sheep and the pig were only 5 or 6 months old. In general, on the same food rations, the castrated animals fattened more readily than they had before operation. Castration had an immediate, marked effect on body temperature and heart rate, but this effect was only temporary and both functions rapidly returned to their normal levels. The respiratory exchange measurements indicate that castration of these animals at the ages of puberty and adolescence results in a decrease in the energy needs of from 5 to 10 per cent. The greater part of the effect is ascribable to the absence of the testicular hormone. It is conceivable that the effect would be still greater in the case of animals castrated after having attained complete maturity.

- (7) *The basal metabolism of the goat.* Ernest G. Ritzman, Lloyd E. Washburn, and Francis G. Benedict. Univ. New Hampshire, Agric. Expt. Sta., Tech. Bull. 66, 1936. 28 pages.

Eighteen goats, of both sexes and young and adult ages, were studied under basal conditions. The rectal temperature averaged 39.1° C., and the heart rate 81 beats per minute. So far as these two factors are concerned, sheep and goats appear to function identically, the average body temperature of sheep being 39.2°, and the average heart rate 78 beats. The basal metabolism of the goat, expressed per 10 w<sup>2/3</sup> (700 calories, on the average), is below that of any other farm livestock with which measurements have been made. Even the sheep, which is nearest to the goat in size, has a basal heat production on this basis appreciably above that of the goat. An explanation for the goat's low metabolism is not at hand.

- (8) *Chimpanzee metabolism.* Francis G. Benedict and John M. Bruhn. Proc. Nat. Acad. Sci., vol. 22, pages 394-397 (1936).

Twenty-two chimpanzees, ranging in weight from 3 to nearly 50 kg. and in age from 2 months to 15 years and including both sexes, have been studied. The zone of thermic neutrality for the chimpanzee accustomed to heated quarters during the winter is between 20° and 29° C., corresponding closely to that for man. The amount of hair covering plays little

rôle in the conservation of heat at these temperatures. The metabolism varies considerably from day to day. No evidence was found of a sex difference or of an age effect in the heat production expressed per 10 w<sup>2/3</sup>. In these two respects the chimpanzee differs from humans.

- (9) *The physiology of the elephant*. Francis G. Benedict. Carnegie Inst. Wash. Pub. No. 474, 1936. vii + 302 pages, 8 plates, 13 figures, and 43 tables.

In this monograph are reported the findings obtained in an intensive study of sixty-three adult, Indian, female elephants, the largest of which weighed 8000 and 9000 pounds. The unique feature of the investigation was the study of the respiratory exchange (oxygen consumption, respiratory quotient, methane production, and water-vapor output) in a specially constructed open-circuit respiration chamber. The basal heat production of the elephant is 13 calories per kilogram of body weight and 2060 calories per square meter of body surface per 24 hours. Speculations are made regarding the basal metabolism of the whale. An extensive bibliography is appended of the literature dealing with the physiology, anatomy, and other phases of the elephant.

- (10) *The heart rate of the elephant*. Francis G. Benedict and Robert C. Lee. Proc. Amer. Philos. Soc., vol. 76, pages 335-341 (1936).

By means of a 4-stage radio amplification for transmittal of the action currents of the heart to a sensitive galvanometer and special electrodes, records were obtained of the heart rates of 37 adult, female, Indian elephants. The rates averaged 30 beats per minute when the elephants were standing quietly. The lowest rates in the standing position were 22 and 23 beats per minute. When the elephants were lying, the rates were higher, usually from 8 to 10 beats higher. This is contrary to the findings with the cow, which has a lower heart rate when lying. The older elephants tended to have slightly lower heart rates than the younger ones. In comparative zoology the smallest animals have the highest heart rates. The canary has been reported to have a rate of 1000 beats per minute. The elephant, the largest animal thus far studied, has the lowest heart rate.

- (11) *Studies on the body temperatures of elephants*. Francis G. Benedict and Robert C. Lee. Proc. Nat. Acad. Sci., vol. 22, pages 405-408 (1936).

The average temperature of the urine of the elephant is 35.9° C. The average temperature of the feces is, on the average, 0.7° C. higher, explained by the fermentation processes still taking place in the ball of feces. The body temperature of the elephant can be rapidly and accurately determined by inserting an ordinary clinical thermometer 3 cm. into a ball of feces the moment it is passed, leaving the thermometer there for half a minute, then pushing it in another 3 cm. and, after a further wait of 1½ minutes, recording the maximum reading and deducting 0.7° C. from the same. Rarely should the temperature found be significantly different from 35.9° C. Most mammals have a body temperature of not far from 35° to 42° C. Large farm animals have notably high temperatures but the elephant, the largest mammal, whose heat production is the greatest in proportion to its surface area of all animals thus far studied by the Nutrition Laboratory, has the lowest body temperature of any of the large animals.



- (12) *Nutrition of the elephant*. F. G. Benedict. Problems of Nutrition, State Sci. Inst. Public Nutrition, Moscow, vol. 5, pages 7-20 (1936). Festschrift, 65th birthday of Prof. Schaternikoff. (Printed in English and Russian.)

Study of the eating processes of the elephant, with reference to the movements of the jaws and the degree to which pieces of rubber embedded in bread and eaten by the elephant were damaged or marked by the teeth in the chewing process, indicated that the mastication is apparently poor, in spite of the highly developed tooth structure. In the feces of one elephant several portions of red beets were found that had not been chewed or crushed. Food passes rapidly through the intestinal tract of the elephant. The poor mastication of food and the relatively rapid passage of food through the intestinal tract explain the poor digestibility of hay (40 per cent) by the elephant.

- (13) *Basal metabolism of normal young men and women of various races in Hawaii*. Carey D. Miller and Francis G. Benedict. Trans. 46th Annual Meeting Hawaii Territorial Med. Assoc., Honolulu, May 1936, Scientific Sessions, pages 27-29.

Brief report of results of an investigation that will soon be published in detail by the University of Hawaii.

## TORTUGAS LABORATORY

W. H. LONGLEY, EXECUTIVE OFFICER

## VISITING INVESTIGATORS

During the summer of 1936 the Tortugas Laboratory was open between May 29 and August 18. Due to illness of the Executive Officer, Dr. W. H. Longley, the duties of this office were accepted during the greater part of the season by Dr. Caswell Grave. A list follows of the names of those who made use of the facilities of the laboratory for research with dates of their occupancy of tables and the general subjects of the work of each:

- A. A. Boyden, Rutgers University. Blood relationships among invertebrates. June 11 to July 7.
- L. R. Cary, Princeton University. Growth of *Ptychodera* tissue cells in vitro. July 23 to August 18.
- H. H. Darby, College of Physicians and Surgeons. Development of the chela in crustacea in relation to time, temperature and gamma radiation; The mode of use of the male sex hormone in fishes; The presence of vitamin D in Sargassum plankton. May 29 to August 4.
- Caswell Grave, Washington University. Accelerators of metamorphosis of larvæ of *Phallusia nigra* and species of *Polyandrocarpa*, in collaboration with Paul A. Nicoll. May 29 to August 4.
- Frank R. Kille, Swarthmore College. Regeneration in holothurians. May 29 to July 7.
- M. W. de Laubenfels, Pasadena Junior College. Morphology and physiology of sponges. June 25 to August 4.
- J. F. Leitch, University of California. A physico-chemical study of the eggs of echinoderms, especially the sea-urchins, with special emphasis on the relationship between chemical composition and water exchanges. June 25 to August 4.
- W. H. Longley, Goucher College. Taxonomy of fishes. July 9 to August 18.
- Gordon Marsh, University of Iowa. The relation of light to *E. M. F.* in *Valonia*. May 29 to August 18.
- C. E. Moritz, University of California. Embryology of the sea-hare, *Aplysia protea* and of *Crangon armillatus*. June 11 to August 4.
- Paul A. Nicoll, Washington University. Accelerators of metamorphosis of larvæ of *Phallusia nigra* and species of *Polyandrocarpa*, in collaboration with Caswell Grave. June 25 to August 4.
- R. F. Pitts, New York University. Clearance values of sucrose and creatinin in the kidneys of the grouper, *Epinephelus striatus*. July 9 to August 4.
- H. H. Plough, Amherst College. Regeneration of stolon fragments in *Perophora* and *Ecteinascidia* and a taxonomic study of the ascidian fauna of the Tortugas. June 25 to August 18.
- O. W. Richards, Yale University. Growth studies of *Phallusia nigra*. July 9 to August 4.
- D. H. Tennent, Bryn Mawr College. The effect of irradiation of eggs of *Lytechinus* with sun-light during development in various dyes. July 9 to August 4.
- B. H. Willier, University of Rochester. A study of the early embryology of the Loggerhead turtle and of sharks. May 29 to July 7.

*Serological Study of the Relationships of Some Common Invertebrata,*  
by Alan Boyden

The discovery of some remarkably convergent precipitin reactions between the blood sera of *Callinectes sapidus*, *Bathynomus giganteus*, and *Mithrax verrucosus* made it necessary to determine the cause of these reactions. Lipids were suspected at once for it is well known that certain substances soluble in lipid solvents are irregularly distributed in animal and plant tissues. The fact is that such substances have long been removed from the plant antigens used by Mex and his colleagues, but to date the results obtained with vertebrate blood sera have not indicated any disturbance due to lipids. Here, however, is a striking case where the native sera of not closely related species react practically equally to antisera made in response to the injections of any one of them.

To determine whether lipids were responsible for the aberrant results, several lots of the serum of the common blue crab (*Callinectes sapidus*) were extracted with ethyl ether in extraction chambers of a simplified Friedrich's type. The extraction was performed at room temperature, no special precautions being taken to keep the serum cold. After twenty hours of extraction the ether was removed from the serum by evacuation and the latter filtered through a Seitz filter and stored. An antiserum was prepared to this extracted serum by injection into a rabbit and this antiserum was tested with native (unextracted) blue crab serum, with the extracted serum used for injection, and with the native serum of *Bathynomus giganteus* and *Mithrax verrucosus*. Though the antiserum was a strong one (homologous titer 1:1,280,000) weak or negative reactions were obtained with *Mithrax* and *Bathynomus*. In other words the convergent reactions obtained with antisera to native serum had disappeared following ether extraction.

In an attempt to find out whether twenty-hours extraction was necessary to remove the lipids responsible for these aberrant reactions three other antisera were prepared to blue crab sera which had been extracted fifteen hours, ten hours, and five hours, respectively. The results indicated that five- or ten-hours extraction under the conditions described were insufficient to remove the lipids responsible for the convergent reactions, therefore a fifteen- or twenty-hour period of extraction is necessary.

Hereafter in all studies of blood relationship among Crustacea involving the sera, it must be shown that no convergent reactions due to lipids are present. Some method of lipid extraction must be used which does not denature the proteins. The method described above which worked so well with blue crab serum was found to be inadequate for other species (*Stenocionops spinimana*, *Geryon quinquedens*, *Bathynomus giganteus*), as it resulted in marked protein denaturation.

In order to secure the larger amounts of sera necessary to make a critical study of blood relationship within the Crustacea and Mollusca following the lines suggested above, further collections of blood were necessary. The bloods of ten species of Crustacea and four species of Mollusca were obtained at Tortugas, some of them in large amounts. Particular interest will attach to the results of the tests with *Geryon quinquedens*, as this is a species of somewhat uncertain systematic position. These sera, supplemented by others collected at Beaufort, North Carolina, and at Mount Desert Island, Maine, will provide the materials necessary for what may be the first critical study of blood relationship among the two groups mentioned, based on the serum proteins without their lipids.

*Growth of Tissues of Ptychodera bahamensis in Vitro, by L. R. Cary*

Using a technique previously described in these reports (1932-34) tissues from endodermal caecal pouches of *Ptychodera* were grown in essentially pure cultures for study of their activities by time lapse microcinematography.

Incidental to the more extensive portion of this research, the results of which can not be evaluated until the films have been processed and studied, several points concerning culture methods and growth behavior were given some consideration.

The effect of relatively minor differences in temperature, which varied only between 27° and 34.7° C. from day to day, were sufficient to cause a variation of at least eight times in the lag period between the making of cultures and the first appearance of any marked migration of cells from the explant. This difference when first observed seemed so striking that it was carefully checked under controlled temperatures. Below 29° C. growth started only after a lapse of at least two hours. At 27° C. a four-hour period of inactivity was not uncommon.

At the usual mid-morning temperature of 31° to 33° C., migration would frequently have started within ten minutes after explants were transferred to a cover-glass.

Once started, the rate of migration varied very little at the different temperatures. Activity was slightly more prolonged at the lower temperatures and the proportion of cells which ultimately left the explant somewhat greater.

Harperized plasma of the red grouper, *Epinephelus morio*, coagulated by the use of spleen extract of the same species, was used successfully as a culture medium. Both the blood and the spleen extract were obtained under septic conditions and passed through a Seitz germicidal filter after centrifuging. As satisfactory clots were obtained after filtration of plasma and extract as when they were used immediately after preparation.

So far as these limited observations justify a conclusion, no evidence was found to indicate that filtration had to any appreciable extent detracted from the capacity of the spleen extract as an activating agent.

In general the cultures made in the solid medium showed much slower, but more prolonged, activity than those made in fluid media.

Cultures which had been allowed to go through activity at room temperature for more than half of the normal period could be held at that point in an ice-box at 12° C. overnight. After having come back to room temperature, they could be followed through the remainder of the normal period of activity without any apparent harmful effect from the enforced period of inactivity.

*Studies by H. H. Darby*

CRUSTACEAN DEVELOPMENT

Previous studies on the developmental mechanics of crustacea as observable in *Crangon armillatus* have been continued. When a piece of the dactylus of the pinch-claw is removed and the snap-claw on the other side is also removed, so that at the next molt the pinch-claw is made over into a snap-claw, the following conditions are observed. Depending on the size of the piece of the dactylus removed, there follows a greater or lesser elongation of the propodus. That is to say, the growth materials made available by the absence of the piece of dactylus are used by the propodus. In like man-

ner, by removing pieces from the propodus, it is possible to produce a greatly elongated dactylus. These observations show that competition for growth substrates, which has been shown to exist between the two sides of the animal, is also operative between the two ends of a single claw.

By the use of gamma radiation from radium it has been possible to localize the time of differentiation of the snap-claw to within 4 hours. This amounts to only about 1.5 per cent of the total intermolt period of 10.5 days; which means that the process of differentiation is an exceedingly rapid one. These new data are entirely consistent with earlier findings.

#### A VITAMIN D-LIKE SUBSTANCE FROM SARGASSUM WEED

Preliminary experiments have shown that non-saponifiable fractions from *Sargassum fluitans* and *S. natans* are completely curative when fed to rachitic rats as a supplement to a standard rachitogenic diet. Continuation of this work is now in progress, in order to identify the active principle.

#### SEX HORMONES IN FISHES

In *Fundulus heteroclitus* and *Rhodeus amarus* there is a marked difference in the coloration of the male in the breeding season, as compared with the non-breeding season. It was found possible to produce the breeding season coloration in forty-eight hours by the injection of Testosterone (Ciba). Similarly, following the injection of this material, the immature blue head (*Thalassophryne* sp.) of tropical waters takes on the adult coloration.

#### *Accelerators of Metamorphosis of Larvæ of Phallusia nigra and Species of Polyandrocarpa*, by Caswell Grave and Paul A. Nicoll

Experimental studies of ways and means of accelerating metamorphosis of larvæ of *Phallusia nigra* and species of *Polyandrocarpa* were carried on between May 29 and August 3 with the purpose of identifying substances primarily responsible for the activation of the process of metamorphosis.

The results of this work and that of the two preceding seasons have led to the tentative conclusion that heavy metals in very low concentrations are involved in the final activating reaction, Fe in the case of *Phallusia*, Cu in the case of *Polyandrocarpa*. These investigations will be described in detail in a paper now in preparation for publication.

The fact that many substances, in or with which neither iron nor copper are present, such as lactic acid, CO<sub>2</sub>-free sea-water, hydroxides, amino-acids and iodine have been found to induce significant percentages of metamorphosis when permitted to act on groups of larvæ for several hours, may be accounted for on the assumption that the mechanism of metamorphosis is so intimately connected with the basic structural and physiological organization of a larva that any environmental change, whether chemical or physical, may exert a greater or less determining influence upon it.

Extracts of ascidian tissues having shown very great potency in accelerating metamorphosis that, to a considerable extent, is species specific, attempts were made to isolate from these extracts the substance to which the accelerating action is due. It has been determined that the accelerating fraction is not protein or lipid in nature and that it must have a molecular structure sufficiently stable to resist disorganization by high temperatures and sufficiently small to dialyze through collodion membranes.

The observation made in 1933 that a sea-water extract of Berkshire sand, in which iron is present as an impurity, consistently accelerates metamorphosis, when coupled with the fact that iron and copper are present in the ascidian tissue from which accelerating extracts are made, suggested experiments in which groups of larvæ of both species have been treated with the chlorides of iron and copper in various concentrations. The remarkable effectiveness of these solutions in dilutions of the order of  $1 \times 10^{-6}$  molar (that of copper consistently inducing 100 per cent metamorphosis of *Polyandrocarpa* larvæ in 9 minutes) seems to warrant belief that these heavy metals are an essential part of the mechanism of metamorphosis of the species under investigation.

Work was also done to determine the extent and limits of variability of untreated *Phallusia* larvæ in the duration of the free-swimming period under a set of constant laboratory conditions. At several intervals during the summer, data were collected from which nine curves of frequency of metamorphosis were constructed, each representing many hundreds of larvæ of the same age and parentage segregated in shell vials, each vial containing approximately 100 larvæ in 10 ml. of sea-water. These curves show that in a batch of larvæ produced near the beginning of the breeding season, 100 per cent metamorphosis is not reached before about 48 hours after hatching, while all larvæ of a batch produced six weeks later may be expected to have metamorphosed within 30 hours, the first cases of metamorphosis on the first curve appearing near the 6th or 8th hour; on the last curve before the 3d hour.

It was demonstrated by other work that changes in the unit-volume of sea-water per larva have a profound effect on the duration of the free-swimming period of *Phallusia* larvæ; 100 per cent metamorphosis taking place in groups of approximately 450 larvæ in 10 ml. of sea-water within a period of 24 hours, but that the same number of larvæ of the same batch in 250 ml. of water require about five days for 100 per cent metamorphosis.

Several experiments were made on larvæ of *Phallusia* and *Polyandrocarpa* to verify the findings of Bradway (1936, Jour. Exper. Zool., vol. 72) that "inorganic" iodine in sea-water in a concentration of 1:80,000,000 ( $5 \times 10^{-8}$  molar) hastens metamorphosis in larvæ of *Clavelina huntsmani* to the extent of 51.8 per cent more than controls, and that in a concentration of 1:40,000,000 ( $1 \times 10^{-7}$  molar) larvæ are killed within 3 minutes. We found that metallic iodine must have a molar concentration in sea-water of  $1 \times 10^{-5}$  in order to have its maximum effect, and that this concentration induced only 16 per cent metamorphosis in *Phallusia* larvæ in 6 hours, the control showing 6 per cent; 85 per cent metamorphosis in larvæ of *Polyandrocarpa* in  $3\frac{1}{2}$  hours, 31 per cent occurring in the control. To be toxic to these larvæ, iodine must have a molar concentration greater than  $2 \times 10^{-4}$ .

#### *Regeneration in Holothurians, by F. R. Kille*

As a result of autotomy, the sea-cucumbers of the genus *Holothuria* lose that portion of the alimentary canal between the œsophagus and the cloaca, the left respiratory tree and the rete mirabili. In order to study the manner in which the digestive system is reconstituted, autotomy was induced by means of electrical stimuli in *H. impatiens* and *H. floridana*. Following evisceration the animals were returned to the ocean bottom in wire cages partially filled with sand and coral. Individuals were then killed and fixed for histological examination at intervals of every second day over

a period of 44 days following autotomy. From a group of 66 *H. impatiens*, 32 lived until killed for examination, while in the case of *H. floridana* 25 survived from a group of 61.

Macroscopic examination within 10 days after evisceration usually revealed an opaque condition of the margin of the transparent mesentery. In addition one can identify a small, blind, tubular rudiment growing anteriorly from the cloaca and a second one growing posteriorly from the oesophagus. Both of these rudiments involve the edge of the mesentery throughout their entire length. Eventually these tubes unite to form a continuous canal connecting the two remnants of the original alimentary canal. This stage was reached by most individuals within 25 days, but there was great variation in this respect. In one small specimen a continuous rudiment had formed in 10 days. In contrast to this, three of the specimens examined 36 days after evisceration showed no signs of activity at the free edge of the mesentery except the opaque condition noted above. The relative contributions of the mesentery and the remnants of the original alimentary canal to the newly formed digestive system must await histological examination of the fixed material.

Evidently autotomy seldom occurs naturally in these two species during June and July. None of the 110 *H. impatiens* was in a state of regeneration, but four specimens among 65 *H. floridana* in this condition were found. On the other hand, in *H. parvula*, which undergoes transverse fission, approximately 15 per cent of 600 individuals were regenerating either a posterior or an anterior end. A group of the latter was fixed with a view to the study of the origin of the gonad and the lantern along with its associated structures.

### *Morphology and Physiology of Sponges, by M. W. deLaubenfels*

In previous summers the existence of photosynthesis had been demonstrated within the three common and readily handled local species, *Iotrochota birotulata*, *Haliclona longleyi* and *H. rubens*. The contained symbiont for *H. longleyi* has been identified as a cyanophycean of the genus *Chroococcus*. *H. rubens* is no longer common at Tortugas. Repeated efforts were made to culture the symbionts from *Iotrochota* with partial success, and their identification may be possible from preserved material.

When cut in two, sponges sometimes heal over the exposed surface as rapidly as within six to eight hours. Such a healed surface has the special ectosomal cells placed as in normal dermal structure. On the other hand the ectosomal cells do not form normal dermis on sponges that are regenerating after dissociation. By the use of the Zeiss Epi-condenser (reflected light) it was possible to see that this process of rapid healing involves the migration to the surface of special dermal cells scattered in the canal linings, overlooked in my previous work because of their dispersed condition. The regenerating sponge has no canals along which such cells may migrate, and unlike the more common endosomal amoebocytes they can not, or do not, migrate through the mesogloea.

It was hoped to make comparisons to the development of newly attached sponge larvae as well. All through the summer very numerous local species, including *Iotrochota*, are loaded with embryos apparently just ready to become free swimming, but not a single free-swimming larva could be obtained, either from collected adults (the normal method) or from repeated plankton hauls.

The vicinity was searched very carefully for commercial type sponges, with the aid of a professional sponge fisherman who is a member of the crew at the Laboratory. The number of commercial varieties occurring locally was thus discovered to be greater than had previously been known to be the case. An earnest effort is being made to correlate the accepted scientific terms with the trade names employed in industry, a correlation never yet satisfactorily made by anyone.

About half a dozen other perplexing minor problems in the natural history of sponges were investigated, and two or three cleared up nicely, but the major work of the summer proved to be a very extensive demonstration of the extent to which syncytial structures of a type occur in sponges.

Using the methods elaborated over twenty-five years ago by Van Tright, and simple methods especially devised for rapid sectioning of living sponges under water, their morphology and histology was investigated in the living condition. When using such a technique one does not see the chondriosomal nor intra-nuclear structures, but the assurance that post-mortem artifacts are absent renders it a very worth-while form of histological investigation. Sponges of the orders Keratosa, Haplosclerina, Pœcilosclerina, Halichondrina, Hadromerina and Carnosa were investigated, giving a wide range of sponge morphology. The syncytial type of organization was found to be very much more emphasized in the Keratosa than in the other orders, the mesoglœa nearly or quite absent. In the latter two a stiff colloidal gel replaces the combination of spongin and sol of the Haplosclerina and Pœcilosclerina.

*Further Physico-chemical Studies of Marine Animals, by James L. Leitch*

The summer's work may be summarized under three headings: (1) water relations of the eggs of *Echinometra lucunter* and *Lytechinus variegatus*; (2) chemical study of the pigments of some echinoderms; and (3) detection and preliminary study of the copper and iron in the tissue extracts used by Doctors Grave and Nicoll to accelerate ascidian metamorphosis.

During the period June 28 to August 2, specimens of *Echinometra lucunter* were brought into the laboratory, washed in tap water and inverted in finger bowls. However, since spawning did not take place, no further data could be obtained on the physico-chemical properties of the eggs of this species.

The eggs of *Lytechinus variegatus*, when observed under high magnification (x 500), were found to be non-spherical in the majority of cases. Measurements of two diameters, at right angles to each other, varied approximately 5 per cent. This slight difference was not detected under lower magnifications since the variation in any pair of measurements was approximately equal to the variability of duplicate measurements of the same diameter. In one experiment with a group of spherical eggs from a single female, the value for the non-solvent volume, as calculated from the equilibrium volumes attained after two hours' exposure to 60 per cent and 70 per cent sea-water solutions, were 22.9 and 23.1 per cent, respectively. For another similar experiment on a second female with spherical eggs employing 60, 70 and 80 per cent sea-water solutions, the values for the non-solvent volume were 19.0, 7.0 and 28.6 per cent, respectively. No explanation can as yet be offered for the great variability in the latter experiment which gave the highest and lowest values obtained in 23 experi-



ments. Analytical samples were prepared for each group of eggs used in all experiments.

The great variability in the color of both the test and gonads of *Lytechinus variegatus* was noted. Preliminary work indicates the presence of two pigments in the test of this species, one a green and the other reddish. The gonads varied in color from a dark brown to a light ochre. No relationship between sex and color of gonads could be found, although the sex of many specimens with dark brown gonads could not be ascertained. Alcoholic extraction of the gonads resulted in the removal of an ochre pigment, not as yet identified. The color variation may be related to the concentration of the pigment, although further chemical analyses may show actual chemical differences.

For comparative purposes, the pigments of the tests or body wall were isolated from the following echinoderms:

- (1) Echinoidea: *Eucidaris tribuloides*, *Echinometra lucunter*, *Centrichinus antillarum*.
- (2) Holothuroidea: *Holothuria parvula*, *H. floridana*, *H. impatiens*, *H. mexicana*, *Actinopyga agassizi*, and a species of *Holothuria* not yet identified.

In cooperation with Dr. Grave and Dr. Nicoll preliminary analytical work involving the microdetermination of copper and iron was started on the tissue extracts used by them in experiments on the metamorphosis of ascidian larvæ. Samples were also prepared of the tissues and test of *Phallusia nigra* and *Polyandrocarpa* sp. (either *tincta* or *gravei*) for detailed analyses, special emphasis to be placed on the presence of copper and iron and the nature of the combination of these two elements in the tissues.

#### *The Photoelectric Effect in Valonia, by Gordon Marsh*

The effect of light upon the inherent potential of impaled *Valonia ventricosa* was studied, using as a light source a 400-watt and a 500-watt tungsten filament lamp. The experiments were performed in a photographic dark room with the experimental material contained in a light-tight box. Light intensity was controlled by varying the distance of the source from the cell; a record was kept of the voltage across the source. The Ag:AgCl electrodes employed were unaffected (or equally affected) by illumination. Potentials were measured with a Compton quadrant electrometer to within 0.15 millivolts. The temperature of the cell was recorded, but uncontrolled; an electric fan held the temperature below 37° C. when the lamp was near. The potentials were corrected for temperature by the  $Q_{10}$ 's previously established. The results agree with those obtained previously (Year Book No. 34, 1934-35, 89-90) with north sky light, save that with the tungsten lamp red is more effective than blue light. The difference between the two sources is evidently correlated with their spectral energy distributions. The data are as yet incompletely analyzed and the qualities stated below are approximations.

The curve of E.M.F. against light intensity was determined over the range from 0- to 7000-foot candles. An intensity of 45-foot candles was necessary to produce a clearly measurable increase over the dark potential. From the dark potential the E.M.F. rises as a sigmoid curve, reaching a maximum at about 1150-foot candles. The region of most rapid rise is from 100- to 500-foot candles. As the intensity is increased beyond the maxi-

mum, the E.M.F. decreases slightly until it undergoes a rapid drop beyond 3000-foot candles. The form of the entire curve is similar to that for rate of photosynthesis *vs.* light intensity. The decrease at high intensities is qualitatively reversible, but prolonged illumination at high intensities produces an exhaustion effect, the potential recovering only slightly or not at all at lower intensities. Some evidence was obtained to show that this is due, at least in part, to disappearance of  $\text{CO}_2$ . At the highest intensities available, the E.M.F. still remained above the dark level. The latter (6 to 10 millivolts) was found to be 20 to 56 per cent of the level of the maximum in light (20 to 40 millivolts). The exhaustion effect and the E.M.F. decrease at high intensities were not due to injury. Illumination at 7000-foot candles for 8 hours produced no demonstrable harm.

Complete exclusion of light from a well-illuminated cell elicited the characteristic potential: time curve found for exclusion of daylight. Any change in light intensity of the order of three times or greater resulted in a transition curve of E.M.F. showing several characteristic spikes and waves, recognizable in form from experiment to experiment. These are interpreted to be the electrical aspect of the change in rate of a definite electrochemical process.

By means of a set of Wratten color filters, it was possible to measure quantitatively the effectiveness of limited regions of the visible spectrum by determining the relative intensities of the filtered and unfiltered light necessary to produce the same E.M.F. The ratio of intensities for a given filter was found to be independent of the absolute intensity (and the E.M.F. matched) and could be reproduced with different cells. When the energy distribution of the source is taken into account the results suggest that the effectiveness of different regions of the spectrum possesses a contour similar to that of the absorption curve of chlorophyll. The curves of E.M.F. *vs.* light intensity and the transition curves of E.M.F. in passing from one intensity to another were *independent in form and characteristics of the spectral composition of the incident light*. This is strong evidence that it is the total energy absorbed rather than the quality of light that determines the magnitude of the light effect.

A few experiments performed to test the effect of presence or absence of  $\text{CO}_2$  harmonize with the other data in demonstrating that the effect of light is through the photosynthetic mechanism. While the potentials measured are not due to photoelectricity in the rigid sense, several types of experiment demonstrated that an impaled *Valonia* plus a measuring device could be utilized as a photoelectric cell, although not comparable in sensitivity or range to commercial types.

There is evidence that prolonged exposure to light and variations in available  $\text{CO}_2$  produce changes in the magnitude of the dark potential. The light effect and the dark potential are of the same fundamental nature. The E.M.F. is intimately related to the photosynthetic system; the effect of light is apparently a complex one due to released oxygen, the formation of an increased amount of available oxidizable material and, possibly, other factors. From the nature of the potential change with intensity and from other evidence shortly to be published, it appears probable that the light (or dark) response is the immediate result of local changes in oxygen pressure. The results of this study appear to constitute definite proof that the potential difference across the protoplasmic layer of *Valonia* arises from an electrochemical system of the type outlined in Lund's oxidation-reduction theory of bioelectric currents.

*The Development of Tethys (Aplysia) protea, by C. E. Moritz*

The tectibranch, *Tethys protea*, commonly called the sea-hare, can be found at Tortugas in the moat on Garden Key, in the shallow water to the west of Bush Key, or less frequently on Bird Key Reef. The species is not difficult to obtain but is not numerous. A maximum number of nine was seen on one collecting trip to the moat.

Eight adults were brought into the laboratory and kept in aquaria, where they lived well and bred frequently for the 7-weeks period that they were kept. They were daily fed the green alga *Ulva* or the brown alga *Hypnea*, although *Tethys* will eat certain other algæ, such as *Sargassum*.

*Tethys* is hermaphroditic. Copulation is frequent. Several periods of copulation usually occur before zygotes are laid. The first egg mass was laid June 25, 14 days after the *Tethys* were brought into the laboratory. One mass was laid on each of the following dates: July 5, 7, 12, 16, and 19; four were laid July 21, five on July 24, and one mass on July 26. The animals were returned to the moat July 31.

The egg masses are laid as a long string wound irregularly back and forth near the surface of the water. The string is about 1 mm. in width. It consists of a transparent sheath within which lies a coiled series of capsules, each capsule containing from 2 to the more usual number of 8, or more, zygotes. A conservative estimate of the total number of zygotes in one string is about 10,000 to 50,000.

No attempt was made to study the cleavage stages. The embryos begin to move on the fourth day. Hatching occurs the eighth or ninth day. The larvæ possess a well-developed operculated shell and are about 250 $\mu$  in length. They lead a free-swimming existence at least 5 days after hatching, beyond which time they have not yet been carried. A dozen or two larvæ seem to do well if kept in a covered stender dish of clean sea-water and fed finely ground *Ulva*. Feeding diatoms to the larvæ was not tried, owing to the scarcity of diatoms and the lack of time to obtain a good culture.

Organogenesis is difficult to observe in the living young because of their small size. Some degree of torsion occurs during development, for the shell is slightly but clearly asymmetrical. No statement can be made at present as to whether detorsion is demonstrable or not. For further morphological study of these processes, some 200 samples of material, taken at definite intervals, were fixed and preserved.

Some study was also made of the development of the shrimp *Crangon armillatus*. With this species a male and female put in a finger bowl will breed readily if the water is changed daily and a supply of *Ulva* and crayfish meat fed to them daily. Larvæ hatch 14 days after the zygotes are laid. If the ovary is full, the female will moult on the fifteenth day and lay again, no later than the following day. Embryonic material was also fixed and preserved for future study.

*Excretion of Creatine by the Marine Teleost, the Red Grouper,  
by Robert F. Pitts*

Creatine nitrogen may account for as much as 25 per cent of the urinary nitrogen in marine teleost fishes. It is known that although the plasma concentration of creatine is low the urinary concentration may be high.

In the normal adult mammal (dog and man), however, it has been shown that the urine is essentially creatine free, though an appreciable amount is present in the plasma. As the creatine plasma concentration is increased in the dog by parenterally administered creatine, the creatine clearance increases, approaching but not quite equalling the glomerular clearance. It is therefore a problem of considerable interest to determine in the fish the relation between creatine clearance and plasma creatine concentration, and by simultaneous comparison with some measure of glomerular activity gain an insight into the mechanism of the excretion of creatine.

The red grouper, *Epinephelus morio*, was used as the experimental animal, caught in traps and kept during the course of the experiment in a live car suspended in open sea-water. Inulin and creatine were administered by intramuscular injection. Eighteen hours later the bladder was emptied by catheterization and firm pressure on the abdomen, and the urinary orifice closed with a purse-string suture. A blood sample was then taken from the caudal vein. Some 90 to 240 minutes later a second blood sample was drawn, the fish killed by a blow on the head and the abdomen opened and urine removed from the bladder by needle and syringe. Plasma and urine filtrates were analyzed for creatine and inulin and in other experiments where creatinine was administered, for this substance also. Glucose values were also determined after phlorizin administration.

In all, 104 fish were successfully used for clearance comparisons, 67 for simultaneous creatine and inulin comparisons, 17 for simultaneous creatine, inulin and creatinine comparisons, and 10 for simultaneous creatine, inulin and glucose comparisons (phlorizin administered). The inulin clearance has been accepted as equalling the glomerular clearance. The creatine clearance though extremely variable is always considerably higher than the inulin clearance and tends to exceed it more at lower plasma levels than at high. Of the few comparisons of the creatinine and inulin clearances a similar statement may be made regarding the creatinine clearance. The creatine and creatinine clearances are not, however, identical, the substance with the lower plasma level having the higher clearance. The administration of phlorizin depresses all clearances but reduces the creatine clearance so that it approaches the inulin clearance. The glucose and inulin clearances are, within limits of experimental error, identical in the phlorizinized fish.

These results are in accord with the concept that a considerable portion of the creatine excreted by the normal fish is eliminated by a process of tubular secretion over and above that eliminated by glomerular filtration.

*Regeneration of Stolon Fragments in Perophora and Ecteinascidia,*  
by Harold H. Plough

My original plan had been to investigate the phenomenon of self-sterility in the ascidian *Styela plicata*, a problem to which I have already devoted some time on the West Coast of Florida. Quite unexpectedly, however, extensive collecting showed that this species is not present at Tortugas and this problem had to be abandoned.

Instead I took advantage of the opportunity to make as complete a list of the Ascidians of the Tortugas as possible, an investigation which has not previously been undertaken. Altogether 32 species of *Ascidacea* were collected and identified with 4 additional species which may be undescribed. Specimens of all these species were preserved, and notes

on the eggs and larvæ made, with the hope that a complete list may be published in the future. To do so will require extensive collecting during future seasons, since it is probable that many additional species are found on the islands.

About half the available time was given over to an investigation of regeneration of complete colonies of *Perophora*, and of two species of *Ecteinascidia*, from finely divided portions of the growing stolons. It was found that such stolon fragments placed in glass cells would fuse into interwoven strands, form buds, and eventually reorganize into mature colonies. In addition the attempt was made to form composite colonies by mixing stolon fragments from two or more species. In about half a dozen cases these attempts were successful; composite colonies containing tissues of two different species in several combinations being secured. It is not yet known whether actual chimæras were secured, but all the colonies were preserved and are to be studied histologically. The discovery of these facts suggests an interesting program for future work, since the method has important genetic as well as embryological possibilities.

*Growth Studies on Phallusia nigra, by Oscar W. Richards*

Motion pictures were taken through the microscope to illustrate the hatching of the tadpole, metamorphosis and the formation of the young Ascidian which will complete the record begun two years ago. The film record will form the basis for the study of the size changes during early development. Still photographs were taken at intervals to show the growth of a number of small Ascidians for the first nine weeks of growth. Concentrated extracts were obtained of the pigment and parts of the test were prepared for further study.

*Studies on Turtle and Shark Development, by B. H. Willier*

The objective of my research program at the Tortugas Laboratory was to make a study in turtles and sharks of (1) the early stages in the formation of the embryo and (2) gonad organization and differentiation.

The development of the Loggerhead turtle (*Caretta caretta*) was followed daily from the time of laying to within a few days of hatching (over a period of 44 days) and embryos in all stages were carefully preserved for a microscopical study to be made later. An attempt was made to analyze by the agar-plate method of vital staining the manner of formation of the primitive streak. This was unsuccessful owing chiefly to peculiarities in development such as the elevation of the blastodisc and its subsequent firm adherence to the shell.

The following observations are sufficiently complete and significant to place on record here:

(1) For about twelve hours after the egg is laid the yolk-sac (and blastodisc) is separated from the shell by a thick layer of gelatinous albumen.

(2) A few hours later, *i. e.* on or about the eighteenth hour, the uppermost and more liquid half of the yolk extends upward as a cone-shaped elevation, its apex making contact with the shell. This elevation is capped by the blastodisc and appears to dissolve (presumably by enzyme action) its way through the albumen. The area of the shell which thus comes in contact with the blastodisc assumes an opaque whiteness circular in out-

line and of the same diameter as the blastodisc. This white area of the shell gradually increases in diameter as the blastodisc grows, spreading to the equator by the sixth day, and to the opposite pole of the egg about the eighth day. Thus during the first week of development the position and extent of the blastodisc may be ascertained readily.

(3) The blastodisc is always situated on the upper surface of the yolk of the egg as it lies in the nest. The white shell area which forms over the blastodisc is likewise on the upper surface of the egg. As development proceeds, the embryonic part of the blastodisc gradually moves to a position  $45^\circ$  from the original position of the blastodisc at the upper pole. Such a position is reached on or about the twelfth day.

Some evidence indicates that the embryo fails to survive if these relations with respect to gravity are changed by turning the egg upside down in the nest.

(4) The shell of the egg shortly after laying is in a partially collapsed state. It remains in this condition until about the ninth day when the eggs gradually (some more so than others) absorb water from the moist sand and become turgid. The turgidity is usually sufficient to cause a spurt of fluid from an opening made in the shell. Toward the end of the incubation period this turgidity becomes somewhat diminished.

(5) The temperature in one nest examined ranged from  $27.5^\circ$  to  $29.2^\circ$  C. and in a second from  $28.6^\circ$  to  $30.8^\circ$  C. The temperatures recorded were lower during June than during July. The rise which occurred, however, was very gradual, corresponding roughly to a general increase in air temperature.

During the last few days of my visit at the laboratory, eggs of the nurse shark were secured. With the collaboration of Dr. F. R. Kille, methods were worked out for handling the very young blastodiscs preparatory to a projected experimental study. A few blastodiscs were preserved for future anatomical study.

For the study of the structural composition of the gonad and sex-differentiation, I was able to obtain (1) a complete series of stages in gonad development within the turtle, (2) a number of critical stages in the embryology of the sex-glands of the sooty tern and (3) a number of gonads of immature sharks of several species.

*The Effect of Irradiation of Eggs of Lytechinus with Sunlight During Development in Various Dyes, by D. H. Tennent.*

The work done during this period was in continuation of the work on photodynamic action of vital dyes begun during the summer of 1935. Fertilized eggs of the sea-urchin, *Lytechinus variegatus*, were used in the investigation. Five minutes after insemination eggs were transferred to solutions of dye in sea-water, one portion being kept as a diffuse light control and one portion irradiated with sunlight and then brought back into diffuse light. The subsequent development of these two cultures was compared each with the other and with a sea-water control. An attempt was made to find a concentration of each dye which was non-toxic in the diffuse light control, but which became toxic in the irradiated culture. In addition to the concentration of the dye, the effect of duration of irradiation and of increased temperature were considered.

The following table presents the results of the investigation:

Dye	Concentration	Non-irradiated	Irradiated	Effect	Remarks
Picric Acid	1:1,000	Lethal	10 minutes	Lethal	
	1:10,000	Non-toxic	10 "	Non-effective	
	1:20,000	Non-toxic	12 "	Non-effective	
	1:50,000	Non-toxic	12 "	Non-effective	
	1:100,000	Non-toxic	13 "	Non-effective	
Martius Yellow	Saturated sea-water solution.	Lethal	10 "	Lethal	
	1/4 sat. sol. in sea-water	Sub-lethal	10 "	Sub-lethal	A few irregular early divisions and some disintegration.
	1/2 sea-water.				Cytolysis and irregular cleavage.
Janus Green B <sup>1</sup>	1:50,000	Lethal	20 "	Lethal	
	1:100,000	Lethal	20 "	Lethal	
	1:200,000	Lethal	20 "	Lethal	
	1:300,000	Lethal	20 "	Lethal	
	1:400,000	Sub-lethal	20 "	Sub-effective	
Alizarine Red S	1:400,000	Sub-lethal	15 "	Sub-effective	Blister cytolysis.
	1:400,000	Sub-lethal	10 "	Sub-effective	Blister cytolysis.
	1:500,000	Sub-lethal	20 "	Sub-effective	Some disintegration.
	1:500,000	Sub-lethal	15 "	Sub-effective	
	1:500,000	Sub-lethal	10 "	Non-effective	
	1:600,000	Sub-lethal	20 "	Effective	Disintegration.
	1:800,000	Sub-lethal	10 "	Sub-effective	
Thionin	1:25,000	Non-toxic	10 "	Non-effective	
	1:50,000	Non-toxic	10 "	Non-effective	
	1:100,000	Non-toxic	10 "	Effective	Fragmentation and blister cytolysis.
Methylene Blue	1:20,000	Non-toxic	10 "	Effective	Some irregular division and disintegration.
Nile Blue Sulphate <sup>2</sup>	1:600,000	Non-toxic	20 "	Non-effective	Irregular division and cytolysis.
	1:800,000	Non-toxic	20 "	Effective	Eggs killed and some disintegration.
	1:800,000	Non-toxic	10 "	Non-effective	
Cresyl Violet	1:700,000	Non-toxic	20 "	Effective	Blister cytolysis.
	1:1,200,000	Non-toxic	10 "	Sub-effective	
	1:50,000	Sub-lethal	10 "	Non-effective	Cleavage irregular.
	1:100,000	Non-toxic	10 "	Effective	Blister cytolysis.
	1:50,000	Slightly toxic	10 "	Effective	Irregular cleavage and cytolysis.

Nigrosine.....	1:20,000.....	Non-toxic.....	20 "	Effective.....	Blister cytotoxicity and disintegration.
	1:20,000.....	Non-toxic.....	15 "	Effective.....	Blister cytotoxicity and disintegration.
	1:20,000.....	Non-toxic.....	10 "	Non-effective.....	Normal cleavage.
	1:75,000.....	Non-toxic.....	20 "	Non-effective.....	
Brilliant Green.....	1:150,000.....	Non-toxic.....	20 "	Lethal.....	
	1:50,000.....	Lethal.....	20 "	Lethal.....	
	1:100,000.....	Lethal.....	20 "	Sub-lethal.....	
	1:200,000.....	Sub-lethal.....	20 "	Effective.....	Blister cytotoxicity.
	1:400,000.....	Non-toxic.....	20 "	Effective.....	Blister cytotoxicity.
	1:400,000.....	Non-toxic.....	15 "	Effective.....	Blister cytotoxicity.
	1:400,000.....	Non-toxic.....	10 "	Effective.....	Blister cytotoxicity.
Basic Fuchsin.....	1:50,000.....	Sub-lethal.....	10 "	Sub-lethal.....	
	1:100,000.....	Non-toxic.....	10 "	Effective.....	Blister cytotoxicity.
Rosolic Acid.....	Sat. sol. in sea-water.....	Non-toxic.....	20 "	Effective.....	Infrequent division and some disintegration.
	4 c.c. sat. sol. in distilled water: 250 c.c. sea-water.....	Non-toxic.....	20 "	Non-effective.....	
	1 c.c. sat. sol. in distilled water: 250 c.c. sea-water.....	Non-toxic.....	20 "	Non-effective.....	
Pyronin <sup>3</sup> .....	1:25,000.....	Lethal and blister cytotoxicity.	20 "	Lethal.....	Disintegration.
	1:50,000.....	Lethal and blister cytotoxicity.	20 "	Lethal.....	Blister cytotoxicity.
	1:100,000.....	Lethal.....	20 "	Lethal.....	Blister cytotoxicity.
	1:150,000.....	Non-toxic.....	20 "	Effective.....	No cleavage and general blister cytotoxicity.
	1:150,000.....	Non-toxic.....	10 "	Effective.....	About 1/2 blister cytotoxicity.
Rhodamine B.....	1:25,000.....	Non-toxic.....	20 "	Effective.....	None divided and many disintegrated.
	1:25,000.....	Non-toxic.....	10 "	Sub-effective.....	Irregular cleavage after 1st division.
	1:50,000.....	Non-toxic.....	20 "	Non-effective.....	Regular cleavage.
Thymol Blue.....	2 c.c. sat. sol. in distilled water: 250 c.c. sea-water.....	Non-toxic.....	20 "	Non-effective.....	Regular cleavage.
Fluorescein.....	1:10,000.....	Non-toxic.....	Pre-irradiated for 2 hours.	Non-effective.....	
		Non-toxic.....	20 minutes.	Effective.....	Blister cytotoxicity.
Eosin Y.....	1:12,500.....	Non-toxic.....	20 "	Non-effective.....	Regular cleavage.
	1:25,000.....	Non-toxic.....	20 "	Non-effective.....	Regular cleavage.
	1:50,000.....	Non-toxic.....	20 "	Non-effective.....	Regular cleavage.

See notes on page 96.



## NOTES FOR TABLE

<sup>1</sup> Stock solutions of Janus Green undergo deterioration quickly. In order to get consistent results from day to day, freshly prepared solutions must be used.

<sup>2</sup> In attempts to make Nile Blue A solutions of a concentration stronger than about 1:500,000 by adding distilled water solutions of the dye to sea-water, the dye was precipitated in the sea-water leaving a light lavender solution of about the same color as that given by a saturated solution of Nile Blue A in sea-water.

Subsequent experiments indicate that it was precipitated as a chloride. After further work with more dilute solutions it became evident that even the bright blue 1:700,000 solution of Nile Blue A in sea-water was a supersaturated solution. The eggs in this solution take up the stain more quickly in the irradiated solutions than in the non-irradiated, until the solution becomes steel gray in color, this color being the same as that shown by saturated sea-water solutions of Nile Blue A made by dissolving the dye directly in sea-water. The most effective staining results were obtained with the 1:600,000 solutions. In this the blue granules (fatty acids) were very sharply defined; the periphery of the egg was free from granules, these being clustered around the nucleus. Some granules showed a clear center with a blue rim.

<sup>3</sup> Blister cytolysis was produced in non-irradiated 1:25,000 solutions, and in both non-irradiated and irradiated 1:50,000 solutions. The eggs in the irradiated 1:25,000 were killed before blister cytolysis could occur.

# GEOPHYSICAL LABORATORY<sup>1</sup>

ARTHUR L. DAY, DIRECTOR

## PROGRESS IN EQUILIBRIUM STUDIES OF ROCK-FORMING SILICATES<sup>2</sup>

All mineral substances with which we are familiar have had their ultimate origin in molten material that has risen from the depths and, upon cooling in the crust of the earth or at the surface, has given solid rocks known as the igneous rocks. Geologists have long studied these rocks and found that they present almost bewildering variety. In part this variety is plainly due to the different conditions under which solidification took place, but there are also fundamental distinctions of chemical and mineral composition. Investigation of the relation of type to type has led to the conclusion that some of this variation arises during the process of consolidation (crystallization). Since the geologist sees only the end-product, it has been realized that a great increase in our knowledge would accrue if mineral melts were studied by laboratory methods and the process of consolidation of these melts were observed under controlled and measured conditions. Studies of equilibrium between crystalline minerals, usually silicates, and their melts have accordingly been a major part of the program of the Geophysical Laboratory.

To carry out these investigations it has been necessary to develop a special technique which has been improved from time to time as occasion demanded. First studies were concerned with single minerals or simple mixtures. Later it proved possible to extend the work to more complex compositions. Some silicates and mixtures of silicates were found to lend themselves more readily to investigation. In these equilibrium was attained in periods of time measured in hours or even minutes. Other mixtures were found to require days, weeks or even months for the attainment of equilibrium.

Progress was naturally more rapid with silicates of the former type. Much information was accumulated regarding crystallization equilibrium in mixtures of certain pyroxenes, olivines, lime feldspar and other minerals characteristic of the more basic (mafic) rocks. Silicates of the other type, the characteristic minerals of the salic and alkalic rocks, yield their secrets more slowly but, with the development of a special method of thermostatic furnace control, and after long-continued cooperative effort of a number of workers, substantial results are now available. Equilibrium in mixtures of the soda-alumina silicates, albite and nepheline, was first determined (Greig) and the investigation was then extended to mixtures containing potash-alumina silicates as well. The results of these studies are expressed in the equilibrium diagram (fig. 1). The crystalline phases represented include the familiar minerals leucite, nepheline, the alkali feldspars and silica. The only important feature of the diagram to which attention can be called in this brief note is the region of low-melting mixtures whose location is readily made out by inspection of the isotherms. Mixtures lying in

<sup>1</sup> Situated in Washington, District of Columbia.

<sup>2</sup> N. L. Bowen, J. F. Schairer.

this region approach closely in composition to the phonolites, trachytes and rhyolites, the most abundant of the alkalic and salic rocks. The results thus constitute further evidence of the formation of these rock types from the residual liquids of fractional crystallization.

Progress in the study of these silicates which attain equilibrium with great reluctance has been materially aided by finding a method of investigation applicable to the iron silicates. Unlike the sluggish mixtures, the iron silicates attain equilibrium promptly. The difficulty with the iron silicates

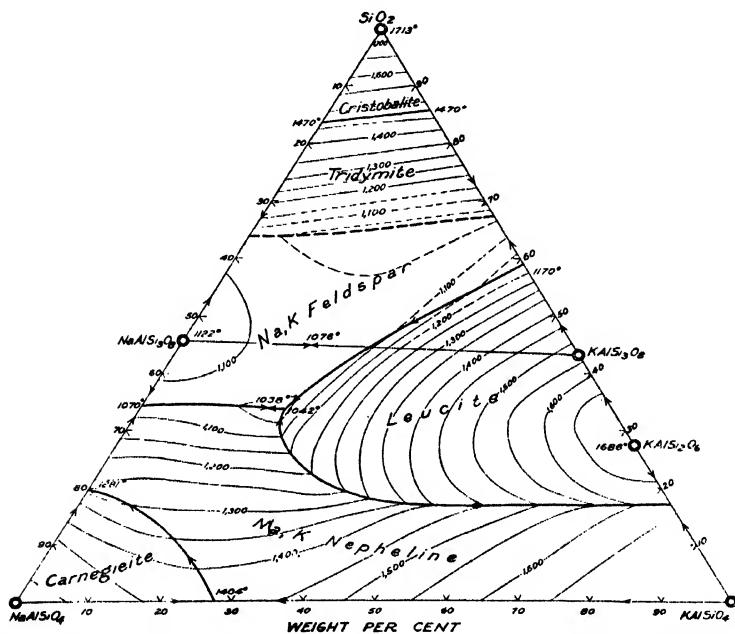


FIG. 1—Equilibrium diagram of the system,  $\text{NaAlSi}_3\text{O}_8\text{-KAlSi}_3\text{O}_8\text{-SiO}_2$ .

was to find a container that was adequately inert. With the solution of this difficulty and the attainment of significant results upon a number of iron-bearing silicates and their mixtures (Ann. Rept. of Director 1931-32) a method of facilitating the attainment of equilibrium in mixtures of the sluggish type becomes available. It is only necessary to add an iron silicate to such mixtures and it is found that equilibrium can be obtained in reasonably short periods of time. A beginning was made by adding the iron olivine, fayalite, to albite, which ordinarily crystallizes very reluctantly. The result was that albite crystals were readily obtained and the equilibrium relations in all mixtures have now been determined. They are presented in figure 2, an important feature of which is the location of the eutectic at 84 per cent albite. The lowest-melting mixture is, then, albite-rich, not fayalite-rich.

Mixtures of albite and fayalite were chosen in the first investigations of this kind because they are related to and constitute a mode of approach to compositions corresponding with the natural rocks known as fayalite trachytes, phonolites and rhyolites, a field study of which has been made by Bowen in the Great Rift Valley of Africa (Ann. Rept. of Director 1929-30). The rocks are rich in alkali feldspar, not fayalite-rich, and thus seem again to have the characteristics of low-melting, residual liquids.

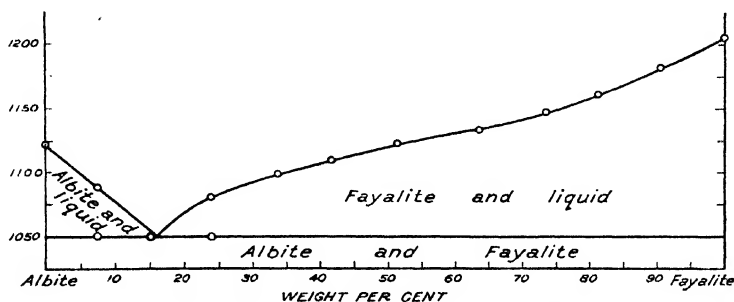


FIG. 2.—Equilibrium diagram of the system, albite-fayalite.

Such rocks are of wide-spread occurrence, having been described from islands of the Mediterranean, the North Atlantic, the South Atlantic, the Japan Sea and elsewhere, apparently all regions of crustal foundering. It is expected that continuance of equilibrium studies now in progress will throw further light on the equilibrium relations of these rocks and therefore upon their mode of origin.

#### INVESTIGATIONS OF THE THERMODYNAMIC PROPERTIES OF SILICATE-WATER SYSTEMS<sup>1</sup>

A considerable portion of the data accumulated at the Geophysical Laboratory during the last twenty-five years concerns phase equilibria of rock-forming silicates at atmospheric pressure. In this work the liquid phases or solutions have been "dry melts" wherein the variables concerned are temperature and concentration, and these investigations have been simplified by the fact that, for the conditions of temperature and silicate combinations ordinarily encountered, rock-forming silicates are found to be miscible in all proportions in the liquid state. Any exceptions which have been established (Greig, Pub. Geophys. Lab. Nos. 630 and 649; Ann. Rept. of Director 1927-28) lie outside the temperature region herein considered.

There is an important field of igneous phenomena manifested in deep-seated activity by pegmatites, ore deposits, intricate replacements of neighboring rock, in surface activity by volcanic explosive phenomena and other related features, which is not as yet adequately explored. In order to understand the nature of these manifestations it is necessary to consider the effects of volatile constituents. Furthermore the introduction of a volatile component will also act to modify the stability fields of the silicate compounds or minerals.

<sup>1</sup> R. W. Goranson.

To carry out work on silicate systems which include volatile components an entirely new technique must be developed because here pressure becomes an essential variable. Within the last ten years apparatus and technique have been perfected for carrying out such work to pressures of 4000 bars (which corresponds to a depth of nearly 15 km below the surface of the earth), and investigations are being conducted on systems of rock-forming silicates with water included as a component.

In these systems there are present in general two fluid phases, one phase predominating in silicate content and the other in water content, because water is relatively insoluble in rock-forming silicate melts. It is necessary, therefore, as part of these investigations to evaluate the solubility relations of water in the silicate melt as a function of temperature, pressure, and composition of the silicate solvent. Although it was found that the absolute values of the solubilities varied appreciably with the composition of the solvent, nevertheless the general trend of the pressure-water concentration curves for a very considerable range of pressure appears now to be fairly well established. A hyperbolic equation,  $x = p/(a + bp)$ , where  $x$  denotes the weight concentration of water,  $p$  pressure in bars, and  $a$  and  $b$  positive quantities which are constants for constant temperature and silicate species, was found to express satisfactorily the solubility relations in the silicate species which have been investigated up to the present time. These include a granite from Stone Mountain and the compositions represented by orthoclase, orthoclase-silica, and albite. The temperature coefficient of solubility, although not yet well established, is negative and apparently a linear function of temperature within the interval investigated. Solution of water is found to be an exothermic reaction, that is to say heat is evolved when water is dissolved in, and absorbed when water is evaporated from, the silicate glass. (Pub. Geophys. Lab. Nos. 764 and 908; Ann. Rept. of Director 1930-31, and 1935-36 *et seq.*)

It is to be expected that the presence of water as a constituent of the system will act in a differential manner on the silicate components to modify the fields of stability of the silicate minerals as well as their relative positions in the temperature-pressure-concentration coordinate space. There are, however, at the moment, no thermodynamic data from which any deductions or generalizations can be drawn. Thus, even though it might not be particularly surprising to find experimentally that the field of leucite in the system orthoclase and water disappears at about 3000 bars, yet such a fact would have been unpredictable.

The majority of silicate compounds behave "normally," which means that their melting temperatures are raised by an increase in the hydrostatic pressure on the system, but when water is present as a separate phase the initial effect of an increase in the external pressure is to lower the melting point. The rock-forming silicates studied in these investigations have, however, no point of maximum pressure, *i.e.* a point where  $dp/dt = 0$ , along the boundaries of their liquidus-solidus fields such as Morey obtained for sodium and potassium silicates but have, on the contrary, a point of minimum temperature, *i.e.* a point where  $dt/dp = 0$ , above which point any further increase in pressure raises the melting temperature. There are here two counteracting tendencies, at first the effect of an increasing water concen-

tration in the silicate melt predominates, then as the external pressure is increased this effect gradually diminishes until it is counterbalanced by the "normal" pressure effect at which point  $dt/dp = 0$ ; at still higher pressures the latter tendency will then predominate and the net effect will be to raise the melting point.

New phases, represented by hydrated silicate compounds, will come into existence at lower temperatures, but here too the stability relationships of these minerals are unknown and we are investigating practically unexplored territory.

#### CORE SAMPLES OF THE OCEAN-BOTTOM<sup>1</sup>

The interest of this Laboratory was focused on the ocean-bottom and its geophysical significance when it was called upon to make a series of determinations of the radium content of the bottom samples obtained by the yacht *Carnegie* on its last cruise. These 28 samples, together with another suite of 28 taken by the *Challenger* and *Princess Alice II* and tested for radium by Dr. Hans Pettersson, demonstrated the fact that the sediments of the ocean-bottom possess a far greater concentration of radium than do any class of rocks, igneous or sedimentary, as yet examined on land. This fact has far-reaching geophysical connotations.

Nearly all the samples, so far examined, of the ocean-bottom have been "grab samples," i.e. a few cubic centimeters of material scraped from the surface of the bottom. They yielded no knowledge of what lay below—no perspective of sequence or time. In view of the vast area represented by the ocean-bottom and its probable antiquity, some sort of undisturbed core sample was most urgently desired.

The geophysical aspect is not the only one requiring knowledge of what lies below the topmost surface of the bottom of the ocean. For general oceanography this is of the utmost importance in view of the fact that seventy-two per cent of the surface area of the earth is covered by the ocean. The material lying, layer upon layer, in the bottom constitutes the repository of the historical record of this ocean. The record has been accumulating throughout many ages and during many changes in the water above. What has happened in this water is recorded by the remains of many minute organisms which lived and died and evolved into various forms within it, and whose skeletons now constitute much of the accumulated material of the bottom.

Some types of organisms live only in cold, others in warm water, some in shallow, others in deep water, some are associated with more or less fresh water, others only with salty water. Some are known to have lived a long time ago, while others have evolved into their present forms comparatively recently.

Besides these records of past life and its many changes, there exists a chemical and a physical record. Oxidation and reduction and the nature of the dissolved matter in the water have all left the record of their changes in the bottom, and the nature and size of the minerals and rock fragments bear evidence of the strength and direction of former currents, the movement of ice, and the depths of the ocean in the past.

<sup>1</sup> C. S. Piggot.

All these records have been laid down in historical sequence, and in some places this sequence has remained undisturbed throughout many geologic ages. The localities where this sequence has been disturbed and the nature of the disturbance are also important facts in a study of the record.

Far out from land in the undisturbed depths of the open ocean this record has accumulated very slowly, so that a few feet of depth may represent a very long interval of time. Therefore, if we could bring up a vertical section of several feet of this bottom, in its original undisturbed condition, we might read the history of oceanic events as the geologist deciphers the record in the rocks.

The need of such samples has been felt for many years and many devices to secure them have been tried. Recently an apparatus has been developed which has obtained such "cores" up to ten feet in length and containing sufficient material for a very comprehensive study. These cores have been brought up from ocean depths of 2700 fathoms, which is more than three land miles down.

The apparatus is described in detail in the Bulletin of the Geological Society of America (Vol. 47, pp. 675-684, May 31, 1936). It consists essentially of a steel tube (inside which is a thin brass tube) which, on arriving at the bottom, is forced into the sediment by an explosion of cannon powder in a weight or "gun" attached to its upper end. When brought to the surface the sample is contained in the brass tube, which is slipped out and labeled and another tube put in. The sample remains undisturbed in its particular brass tube until opened for examination in the laboratory.

The particular value of these samples, over previous ones, is that the material is available for study in the undisturbed sequence existing in the bottom, and consequently a record of succeeding events can be obtained from it. Particular strata may be traced over wide areas and a knowledge of the succession of events in terms of time and extent may be obtained.

Certain chemical and mineral constituents are of great significance, as for instance the fluorine, manganese, and radium concentrations. The last is generally much greater in bottom sediments than in either igneous or sedimentary rocks on land and this difference is as yet not completely explained. The concentration is highest in those portions of the ocean-bottom most remote from land and lying at the greater depths. The material at the bottom of the great deeps generally consists of so-called red clay, and this material appears to contain many times as much radium as any rocks on land. If these sediments are of considerable depth, and if this radium concentration is the same throughout, these deeps constitute local concentrations of radioactive material possessing enormous stores of energy. In view of the fact that, as yet, no sedimentary rock on land has been found to contain even a small fraction of such radium concentrations, it may be inferred that the many changes of level of various parts of the earth's surface have nowhere brought up an ocean deep. It may be that the deeper portions of the ocean are permanent features of the earth, or else it may be that this radioactivity is only a surface characteristic. The core samples may throw some light on these questions. Furthermore, a study of the radioactive substances and their disintegration products holds the promise of a determination of the time intervals represented by the various strata, or the sediment as a whole. This in itself is of the utmost significance.

The only record of the history of the existing ocean lies buried in its bottom. Whether this record will be easy or difficult to decipher, voluminous or meager, remains to be ascertained, but whatever its nature it is now accessible through these core samples.

### PUBLICATIONS

(892) "Ferrosilite" as a natural mineral. N. L. Bowen. *Am. J. Sci.* 30, 481-494. 1935.

The crystallographic and optical properties of minute needles found in the lithophysæ of an obsidian from Lake Naivasha, Kenya, correspond with those of pure  $\text{FeSiO}_3$  as determined by an extrapolation in series of monoclinic pyroxenes. The occurrence of substantially pure  $\text{FeSiO}_3$  as a natural mineral is rather unexpected, since synthetic studies have suggested that  $\text{FeSiO}_3$  can not occur as a crystalline compound. Critical examination of the results of synthesis shows, however, that the possibility of the formation of substantially pure  $\text{FeSiO}_3$  at decidedly low temperatures is not precluded. The needles may therefore be accepted as having substantially the composition  $\text{FeSiO}_3$ . It is proposed to extend the use of Washington's normative term "ferrosilite" to the naming of the natural mineral also and the name *clinoferrosilite* is therefore given to these crystals. Needles having the same properties have been found in the lithophysæ of other obsidians, including the well-known example from Obsidian Cliff, Yellowstone Park.

(893) Review and discussion of Prof. Paper 179 (U. S. Geol. Survey) by Clarence S. Ross on "Origin of the copper deposits of the Ducktown type in the southern Appalachian region." C. N. Fenner. *Econ. Geol.* 30, 928-936. 1935.

In the Professional Paper that is reviewed, the geologic features of a group of copper-bearing pyrrhotite veins in the southern Appalachian region were described. Study was made of the genetic history and the processes by which the ore minerals were derived from a magmatic body. The author's view was that hydrothermal solutions played the chief part in extraction, and that distillation of the metals in volatile combinations was of little importance. The question of the manner in which ore minerals are derived from a magma is a subject that is much to the fore at present. The reviewer presents and discusses the possibilities of processes that might be considered as factors in the problem, and gives reasons for believing that primary extraction from the magma may have been brought about by distillation in volatile form.

(894) Fabric analysis of a coarsely crystalline polymetamorphic tectonite. Earl Ingerson. *Am. J. Sci.* 31, 161-187. 1936.

Fabric analysis is a new and powerful method of studying all kinds of rocks, especially those whose parts have been differentially moved with respect to one another. (The *tectonites*, as opposed to the *non-tectonites*, which have not undergone such penetrative differential movement.) The method has been developed by the Austrian geologists Sander and Schmidt and is just beginning to be used in this country. The novel idea is that differential movement within a rock produces a characteristic preferred orientation of the component mineral grains, and that this preferred orientation reflects the symmetry and intensity of the motion that produced it. The innovation in technique is the measurement of the orientations of the individual grains with a universal stage, and their statistical study by plotting the orientations of several hundred grains of a given mineral from a given thin section on an equal area projection (Schmidt net). The projec-



tion is contoured to show the preferred orientation of the mineral grains and becomes a fabric diagram. If one makes certain assumptions, most of which are backed by ample experimental data, such diagrams may be made to tell a great deal about the history of a rock that can not be deduced by any other known method.

This paper is the study by such methods of a complex muscovite-biotite schist from Niederthal, Tyrol. Those laboratory methods of fabric analysis that are not elaborated in previous papers in English are discussed somewhat in detail and illustrated concretely by applying each technique as it is described to the study of the schist. The different kinds of diagrams are defined and most of them are illustrated in the study of the quartz fabric of the rock.

The study is a contribution to the regional geology of the Alps, adding to the previously known examples of B oblique B' tectonites an excellent new type of coarser crystallinity than those described by Sander in 1934. It has four visible s-planes, which have been produced by at least two distinct periods of metamorphism. The fabric is analyzed in terms of the individual s-planes and the partial fabrics correlated with that of the whole rock, which is a B-tectonite fabric. The different s-planes are correlated with the proper periods of metamorphism, and the relative ages, intensities, and directions of motion of the two deforming movements are determined.

(895) Bore-hole investigations in Yellowstone Park. Clarence N. Fenner. *J. Geol.* 44, 225-315. 1936.

In connection with the study of thermal phenomena of Yellowstone Park carried out by the Geophysical Laboratory for several years, two bore-holes were drilled in geyser basins. During the progress of this work, temperatures and pressures were measured and observations were made on underground structures shown by the cores. Subsequently the cores were studied in the laboratory by chemical and petrologic methods to ascertain the mineral transformations effected by hydrothermal circulation, and their significance.

Structural features, such as porosity and fractures, together with thermal conditions found, help to explain the underground circulation. The data enable us to picture the manner in which meteoric waters, falling upon adjacent plateau areas, penetrate to deep levels, are met by magmatic exhalations at high temperature, are diverted upward, and appear at the surface as hot springs and geysers. Light is thrown upon the mechanism of geyser action itself, which is found to be a rather more complicated process than has been supposed.

Metasomatic alteration of the rocks has been important. A considerable variety of new minerals has been formed, and the composition has been much changed. The most notable effect found in the cores has been the addition of silica and the molar replacement of soda and lime of the feldspars by potash. The results of this study supplement and confirm those obtained by E. T. Allen in his study of the composition of the thermal springs, carried out as part of the same project. From this assembly of concordant data we are enabled to trace out with considerable confidence a series of reactions that apply not only to the rocks rendered accessible by the drill holes but to those at greater depth, and to deduce the manner in which the original magmatic emanations, dissolved in meteoric waters, have modified the composition of the rocks through which they have passed, and in turn have been modified.

(896) Raman spectra in organic chemistry. James H. Hibben. *Chem. Reviews* 18, 1-232. 1936.

This publication is in the nature of a monograph on the application of Raman spectra to chemical and physical problems with particular emphasis in the field of organic chemistry, and supplies a complete review and bibliography in this field. It continues a similar monograph published in 1933 which dealt primarily with inorganic chemistry.

All the published works on Raman spectra in organic chemistry to date, beginning with the discovery of the Raman effect in 1928, are cited with appropriate references. There are approximately 700 such citations. All the 1370 organic compounds so far investigated are classified as to the type of compound, empirical formula, structural formula and name. In addition to an alphabetical index of all compounds studied, there is a bibliography of all inorganic Raman spectra studies issued since the 1933 review.

The theory of Raman spectra emission is discussed somewhat briefly. The Raman shifts for each type of compound, such as for example, the hydrocarbons, substituted hydrocarbons, ethers, alcohols, esters, acids, ethylene and its derivatives, acetylene and its derivatives, benzene and its derivatives, polycyclic and heterocyclic compounds, etc., have been listed and discussed in detail. The Raman lines attributed to each characteristic type of chemical linkage, such as ethylenic, acetylenic, carbonyl, etc., together with the observed and expected modifications of such lines as a function of chemical composition, have been indicated.

It is shown that the chemical constitution of many compounds both organic and inorganic may be determined with considerable accuracy by the Raman-spectra method. In some instances the heretofore accepted chemical structures will have to be modified. In other instances, where it has not been possible to determine the exact structures chemically, this spectrographic method has clarified disputed interpretations.

In addition to providing a more accurate picture of the arrangement of the atoms in the molecules, it is shown that this method also gives information as to valence angles, valence forces, amplitudes of atomic vibration, energy levels of the molecules, specific heats, latent heats of fusion, and other chemical and physical properties.

The behavior of compounds in solution is occasionally entirely different from their behavior in other states of aggregation. The interactions of the solvent and solute as demonstrated by the Raman spectra are discussed.

In general, the spacial configuration and chemical structure of organic compounds are more thoroughly understood than the more complicated inorganic compounds. If a spectroscopic method will not give reasonable and consistent results with organic compounds its utility in the field of mineralogical and inorganic chemistry will be limited. The results described in the organic field demonstrate the complete utility of this method in other branches of chemistry.

(897) A simplified apparatus for high hydrostatic pressures. L. H. Adams. *Rev. Sci. Instr.* 7, 174-177. 1936.

Although the technique for obtaining and measuring high hydrostatic pressures is now quite well known, the apparatus ordinarily used is elaborate and costly, and requires much time to construct and keep in order. A simple type of high-pressure apparatus has been developed and used successfully in the Geophysical Laboratory. It is inexpensive, easy to operate, and suitable for precise measurements of many kinds. Pressure is generated in a hardened steel cylinder, or bomb, which has a piston actuated by a

hydraulic press. The piston-packing consists of a rubber stopper and a layer of oil, which floats on the pressure-fluid (water or any liquid or solution immiscible with oil). A pressure of 10,000 atmospheres is readily obtained, and is measured by means of a glass piezometer.

- (898) Henry Stephens Washington. Tom. F. W. Barth. Min. petrog. Mitteilungen (Z. Krist., Abt. B) 47, 371-372. 1936.

### Biographical sketch of the late Henry Stephens Washington.

- (899) The crystallization process of basalt. (A supplement and a reply.) Tom. F. W. Barth. Am. J. Sci. 31, 321-351. 1936.

The essential mineral phases of ordinary basalts are plagioclase feldspars which form a reaction series from calcic to sodic with or without individual crystals of alkali feldspar as the last product, and pigeonite pyroxenes which form a reaction series from diopsidic to clinohypersthene.

Depending upon the initial composition of the basaltic magma either plagioclase or pyroxene will start to crystallize, changing the composition to a point where simultaneous crystallization takes place. An equation has been developed giving the conditions for such a simultaneous crystallization.

Comments on papers by Tsuboi, Kennedy, and Powers are offered.

- (900) Thermodynamics and thermochemistry. R. E. Gibson. Reprinted from *Annual Survey of American Chemistry*, Vol. 10, 1935, pp. 59-77. Chemical Catalog Co., Inc., New York City.

A survey of American contributions to thermodynamics and thermochemistry during the calendar year 1935 compiled upon invitation from the National Research Council. Some two hundred and forty papers were reviewed and the results presented in a condensed form under the headings *Molecular Mechanics, Technique of Measuring Temperature, Thermal Measurements, Volume-Pressure-Temperature-Concentration Relations, Homogeneous Equilibria, Heterogeneous Equilibria, Electromotive Force Measurements*, and the *Thermodynamics of Isotopes and their Compounds*.

- (901) The composition of glass. George W. Morey. Reprinted (somewhat extended) from Sci. Monthly 42, 541-554. 1936.

A popular lecture on the nature of glass, the physical requirements for a successful glass, and the chemical considerations limiting the possible compositions which meet the physical requirements.

- (902) Apparatus to secure core samples from the ocean-bottom. Charles Snowden Piggot. Bull. Geol. Soc. Amer. 47, 675-684. 1936.

As a Research Project of the Geological Society of America an apparatus has been developed which has secured vertical cores of ocean-bottom material up to ten feet in length at depths of 1250 fathoms (7500 feet) and less.

The apparatus consists of a bit, water-port, firing mechanism, cartridge and gun. It may be attached to any sounding line, strong enough to lift it, without any modification thereof. On arriving at the bottom the bit is automatically driven into the sediment by means of a charge of cannon powder. This charge may be modified to meet the varying conditions of depth and resistance of the bottom material. It is contained in a steel cartridge which is loaded for each sounding. The length of the bit limits the length of the sample obtainable. Bits ten feet long have been successfully used. Inside the bit is a thin-walled brass tube which contains the sample. A tube, together with its sample, is removed and a new tube inserted for each sounding. Each sample is therefore preserved, without any change, until opened for study in the laboratory.

The specially designed water-port is necessary to give the bit an "open tube" condition in order that the water may be expelled as the bit enters the bottom at the high velocity imparted to it by the explosive.

The firing mechanism has only three moving parts and is very rugged. A safety pin of hardened steel prevents a premature discharge. The gun is merely a billet of cold-rolled steel with a two-inch "muzzle loading" bore.

Satisfactory cores have been secured from the canyons between the Hudson and the Chesapeake and from beyond the continental shelf off the Hudson gorge.

(903) Nepheline contrasts. N. L. Bowen and R. B. Ellestad. *Am. Mineral.* 21, 363-368. 1936.

In order to determine the relationship between nepheline phenocrysts and the magma from which they separate, the chemical composition has been determined of nepheline from a soda-rich rock, phonolite, typical of the East African Rift, and that of nepheline from a potash-rich rock, melilite-leucite nephelinite, typical of the Central African Rift. The results are given in tabular form together with the composition of the rocks. The two nephelines are respectively soda-rich and potash-rich and thus emphasize the variability of the composition of nepheline and its control by the magma from which they form, a relation brought out in a graph of the composition of the rocks and their nephelines.

(904) The system, albite-fayalite. N. L. Bowen and J. F. Schairer. *Proc. Nat. Acad. Sci.* 22, 345-350. 1936.

The study of the system, albite-fayalite, is a first step in the investigation of phase equilibrium in mixtures of alkali aluminosilicates with ferrous silicates. The system is of the simple eutectic type, the eutectic composition at 84 per cent albite and its temperature  $1050^{\circ} \pm 5^{\circ}$  C. Albite, that most reluctant of crystallizers, readily forms typical twinned crystals in mixtures of this system.

Among natural rocks fayalite trachytes and related types (fayalite-bearing rocks rich in albite) are of wide-spread occurrence, though not abundant, and the investigation of which this is a part is designed to throw light upon the thermodynamic properties of these mineral associations and upon the problem of their genesis. In connection with the hypothesis of their derivation through fractional crystallization the albite-rich character of the eutectic is of particular significance.

(905) Structural and petrologic studies in Dutchess County, New York. Part II: Petrology and metamorphism of the Paleozoic rocks. Tom. F. W. Barth. *Bull. Geol. Soc. Amer.* 47, 775-850. 1936.

This paper constitutes the second part of a joint investigation by the author and Robert Balk, who prepared Part I, dealing with the structural geology (preceding paper in same journal). Part II is devoted mainly to the petrology and especially to the metamorphism of the sedimentary rocks.

The Paleozoic sediments of southeastern New York have been changed by the intrusion of various kinds of magmatic matter contemporaneous with mountain folding. The derivatives of the argillaceous sediments are of special petrographic interest, and the mineral changes induced constitute the chief subject of the paper.

The composition of the various metamorphic minerals, or rather, the range of composition (for most of the minerals are solid solutions), the change of composition with changing grade of metamorphism, the range of stability

in relation to the metamorphism and in relation to the surrounding rock, are all factors that have been investigated in order to shed more light on the origin and evolution of the present rock series. New chemical or optical analyses, or both, are given for the following mineral species: Muscovite, biotite, garnet, staurolite, cyanite, sillimanite, feldspar, tourmaline, hornblende, glaucophane, chlorite, chloritoid. Petrographic descriptions of the several rock types found within the area are given, and 18 new chemical analyses of rocks are published.

Perfect agreement between the chemical composition of a rock and its mineral content has been demonstrated. Generally speaking, therefore, equilibrium has been attained during the recrystallization of this rock series.

Chemical and microscopical rock analyses demonstrate that the argillaceous sediments grade, both mineralogically and petrographically, into gneiss-like rocks, through intermediate stages of slate, phyllite, and schist. The conclusion has been reached, therefore, that during the period of orogenesis, the sediments were subjected to long heating in liquids of magmatic and anatectic origin, which reacted with the sediments and metasomatically changed them into well-defined types of schists and gneisses.

In order to avoid confusion it is proposed to use the term "migmatic" for rocks that have been formed by prolonged heating of pre-existing rock material in liquids of magmatic or paligenic origin, and, in accordance with present usage, reserve the term "metamorphic" for recrystallized rocks derived from pre-existing sedimentary or igneous material without essential anatectic or metasomatic alteration. Migmatic rocks are therefore different from igneous, metamorphic, and sedimentary rocks. A brief survey of this new, four-fold genetic classification of the rock system is given.

It is believed that migmatic rocks have a wide distribution in the pre-Cambrian, as well as among the younger orogenies.

(906) Activity and related thermodynamic functions; their definition, and variation with temperature and pressure. L. H. Adams. *Chem. Reviews* 19, 1-26. 1936.

Thermodynamic functions of various kinds are required in the study of phase equilibria by the "indirect" method. The relation of activity to other thermodynamic quantities is discussed and the definition of activity is put in a form that is readily amenable to the common mathematical operations such as differentiation. Exact definitions of several varieties of other functions such as osmotic coefficient and activity coefficient are given; these are correlated, and the derivatives with respect to temperature and pressure are set forth.

(907) Solutions under high pressure. R. E. Gibson. *Sci. Monthly* 43, 173-177. 1936.

A lecture delivered during the Annual Exhibition of the Carnegie Institution of Washington setting forth in a popular way some of the results obtained at the Geophysical Laboratory on the effect of high pressures on solubilities of solids.

(908) Silicate-water systems: the solubility of water in albite-melt. Roy W. Goranson. *Trans. Am. Geophys. Union*, 17th Annual Meeting, pp. 257-259. Nat. Res. Council, Washington, D. C. 1936.

Investigations concerning the problem of evaluating the stability relations of silicate systems containing the volatile component water are being carried out by the writer at pressures up to 4000 bars. The determination of the solubility relations of these systems is a necessary and important part of such a research.

In this paper are presented the solubility data for the system, albite and water, for the temperature interval 850° to 1200° and pressures to 3300 bars.

Water is found to be relatively insoluble in silicate melts, the concentration depending not only on temperature and pressure but also on the silicate species. It was found, however, that the general trend of the pressure-water concentration curves can be expressed by a two-constant hyperbolic equation for the various silicate species which have been investigated; these include albite, orthoclase, granite glass and a few other silicate mixtures.

The solution of water is an exothermic process and this heat given off on solution varies directly with temperature and inversely with pressure. Conversely heat is absorbed from the system when water is driven out of the melt.

(909) Solubility in the system, KCNS-H<sub>2</sub>O. F. C. Kracek. *J. Wash. Acad. Sci.* 26, 307-313. 1936.

In continuation of studies on solubilities in systems containing volatile components at moderately elevated temperatures, the solubility of potassium thiocyanate in water was determined from room temperature to the melting point of the salt (176.8°C). Potassium thiocyanate undergoes a rapid polymorphic inversion at 140.6°C. In consequence of this, the solubility curve has a break at this temperature. The two branches of the curve can be represented by the equations:

$$\begin{aligned} \text{(a) } \log (100N_2) &= 892.459/T + 7.81532 \log T - 20.71904, \\ &\quad \text{valid between } 140.6^\circ \text{ and } 176.8^\circ \text{C, and} \\ \text{(b) } \log (100N_2) &= -957.918/T - 12.27825 \log T + 0.0108207 T \\ &\quad + 31.85576, \text{ valid below } 140.6^\circ \text{C.} \end{aligned}$$

In these expressions  $N_2$  is the mole fraction of KCNS in the saturated solution and  $T$  is the absolute temperature. A brief thermodynamic discussion of the results is given in the paper.

(910) Separation planes in magnetite. J. W. Greig. H. E. Merwin, and E. Posnjak. *Am. Mineral.* 21, 504-510. 1936.

A number of magnetites showing separation planes were examined to see whether or not they offered any support for the customary explanation of this pseudo-cleavage, *i. e.* that it is parting along the composition planes between twins. No evidence of this could be found. Although the octahedral separation planes are much the most common and best developed, separation planes were also found parallel to some faces of three other forms: (831), (110) and (100). The orientation of the first of these makes twinning extremely improbable, and the orientations of the other two make it impossible, as a cause of the separation planes. Silicate has been deposited in openings along many of these planes. It is believed that the separation planes in these magnetites were developed, without twinning, by differential pressure, much as joints are produced in rocks, but with the crystal structure as well as the differential pressure exercising control.

(911) Annual Report for this year.

(912) The crystal structure of krennerite. (Preliminary communication.) George Tunell and C. J. Ksanda. *J. Wash. Acad. Sci.* 26. 1936.

Well-developed faceted crystals of krennerite from Cripple Creek, Colorado, previously measured by Dr. M. A. Peacock on the two-circle reflection goniometer, were investigated by means of the Weissenberg X-ray goniometer. The dimensions of the unit cell were found to be:  $a_0 = 16.51$

$\bar{A}$ ,  $b_0 = 8.80 \text{ \AA}$ ,  $c_0 = 4.45 \text{ \AA}$ , all  $\pm 0.03 \text{ \AA}$ . The unit cell contains 8 "molecules" of  $\text{AuTe}_2$ . The systematically missing spectra limit the space-groups possible for krennerite to three, namely,  $Pmc - C_{2v}^2$ ,  $Pma - C_{2v}^4$ , and  $Pmma - V_h^5$ . From an analysis of the intensities of the diffraction spots on our Weissenberg negatives, from consideration of the close relationship between the structural lattices of krennerite and calaverite as determined by our Weissenberg studies of single crystals, and from the close similarity of the powder photographs of the two minerals both as to positions and intensities of the diffraction lines, the atomic arrangement in krennerite must be one that is isomorphous with the space-group  $Pma - C_{2v}^4$ . The values of the 18 parameters were determined from the intensities alone. The intensity calculations on which the determination of the atomic arrangement in krennerite rests, and the relationship between the crystal structures of krennerite and calaverite will be discussed in greater detail in a subsequent communication.

(913) The strange morphology of calaverite in relation to its internal properties. George Tunell and C. J. Ksanda. J. Wash. Acad. Sci. 26. 1936.

The structural lattice of calaverite was determined by means of Weissenberg photographs taken with Cr-, Cu-, and Mo-radiation, and the elements of the structural lattice were found to be strictly analogous to the fundamental morphological elements of Goldschmidt, Palache, and Peacock (their *S*-elements). The crystal structure of calaverite has already been described by us (Annual Report of the Director of the Geophysical Laboratory for 1934-35, Carnegie Institution of Washington Year Book No. 34, pp. 101-2); it has the symmetry of the monoclinic system. It was found by Penfield and Ford, by Smith, and by Goldschmidt, Palache, and Peacock that while a number of important faces of the calaverite crystals receive simple indices on the *S*-lattice, the majority of the crystal faces receive indices of great complexity on it. Smith observed that many faces would receive simpler indices if referred to certain triclinic lattices, and this work was extended by Goldschmidt, Palache, and Peacock. In the present investigation a search was made for structural evidence of the triclinic lattices used by Smith and those used by Goldschmidt, Palache, and Peacock, but only one structural lattice was found, and this is analogous to the morphological *S*-lattice, which is monoclinic. However, the complex faces characteristically present on crystals of calaverite have been found to be related, at least in part, to certain adventive diffraction spots on our Weissenberg photographs of calaverite crystals. A complete explanation of these adventive diffraction spots has not yet been found, but our work is being continued. Oriented polished surfaces of several of our calaverite crystals were examined under the reflecting microscope with medium and high power objectives with and without crossed nicols. No inclusions, or twinning, or any kind of departure from perfect homogeneity were visible under the polarizing, reflecting microscope.

## DIVISION OF HISTORICAL RESEARCH<sup>1</sup>

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America and the Pueblo area of southwestern United States. The Section of United States History conducts research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoordinated data which bear upon the acquirement and transmission of ordered knowledge.

The setting up of the Division in 1929 resulted in simplification of administrative procedure and in the achievement of certain economies. The fundamental purpose of the reorganization was, however, to promote intellectual intercourse between all Institution workers concerned with man's career; and through study of topics of common interest to foster attitudes of mind which, it was thought, should lead to clearer formulation of and more effective attack upon the excessively complex problems of social and cultural evolution.

The three groups now functioning as sections of the Division were originally formed for the exploitation of limited and, at first sight, more or less unrelated fields. The groups, for the most part, are still actively pursuing their own special objectives. But certain elements of the sections' researches are gradually being reshaped or reorientated in such a way as to approach fulfilment of the Trustees' desire for a more closely integrated Divisional program. Thus, the study of the Maya, inaugurated as a purely archaeological project, has been broadened to include consideration of the post-Spanish period, thereby bringing it into direct touch with documentary history. At the same time there have been added to the historical group men with interests in Latin America, whose work serves further to bridge the gap between documentary history and archaeology. Lastly, the Section of the History of Science has assigned one of its members to studies bearing upon the vexed question of the correlation of Maya and Christian chronologies.

It is hoped that the above modifications will tend to widen points of view; and, more specifically, that they may produce a nearer alliance between documentary history and archaeology. The latter end is unquestionably most desirable. Both groups are attempting to reconstruct and to interpret the past of the human race. But history deals with peoples whose stories have been perpetuated by the written word; archaeology with those who have left few or, in most cases, no documentary records. This difference in source materials has led to wide divergence of interest. Historians, because their documents, save those of the last few centuries, treat largely of wars and the doings of rulers, have perforce concerned themselves for the most part

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with military and political events. They have accordingly been able to gather relatively little significant information regarding cultural and economic settings. Archæological evidence, on the other hand, consists nearly exclusively of material remains. Hence archæologists have become primarily students of culture and are unable, as a rule, even to speculate as to the enormously important rôles played by individuals, dynasties, or national groupings.

Another factor which has hindered association between history and archæology is the mutual exclusiveness, both geographically and chronologically, of their respective fields of endeavor. Historians devote the lion's share of their attention to recent events in the Mediterranean basin and in Western Europe and to happenings still more recent in regions which Western European civilization has of late invaded; whereas archæologists have to do only with the pre-literate past of the Mediterranean and of Europe, and with the story of other lands prior to the great European outflow. Thus, historians consider in great detail (because their materials are abundant) a short period and a small area; archæologists treat more broadly (because evidence is both scanty and expensive to gather) enormous spans of time and huge terrains. The two disciplines have naturally developed different viewpoints and different methodologies; nor are their findings often readily comparable.

Actual fact-finding as well as judgment regarding the bearing of data upon specific situations must always remain the primary duty of the two specialized groups. But for the carrying out of even such preliminary processes as these, both history and archæology might well profit by association. Archæology needs the aid of the more mature and experienced historical disciplines in development of better methods for the collection, the ordering, and particularly for the evaluation of evidence. The archæological record is still so fragmentary that archæologists, striving to read meaning into it, have tended to reach the stage of reconstructive hypothesis too early. Hypotheses not immediately found fallacious have also too readily been accepted as proven, and search for further pertinent facts has not always been prosecuted with sufficient determination.

While archæological thinking has doubtless been over-loose, historical reasoning has perhaps gone to the other extreme through reliance so implicit upon the written word that nothing is taken into account which is not to be found in documentary sources. Furthermore, the average historian has so strong a predilection for what might be called the narrative aspects of his study that he too often neglects the precious incidental fragments of cultural, racial, or environmental information, the historical potsherds, so to speak, that are tucked away in books and manuscripts.

It seems certain that both disciplines could profit from rapprochement, not only in the matter of mental attitudes and methodologies, but also through better acquaintance with each other's results. Archæology can not interpret its findings save in the light of what history shows that men have done under given conditions; history must turn to archæology for understanding of the prehistoric peoples who laid the foundations of the cultures with which they are concerned.

So while the autonomy of the disciplines should without question be preserved, it is equally clear that mutual understanding and mutual respect should be fostered. And a start toward this highly desirable end can probably most effectively be made by the prosecution of researches in the many fields where history and archæology overlap and where problems of common interest can be made the object of joint attack.

Such cooperative studies have not often been attempted. The Division's program is therefore to a certain extent experimental. One difficulty which can readily be foreseen is that of synthesis. Final summation can certainly never be achieved, even in so relatively small an investigation as that of Maya history. New materials will indefinitely continue to come to light and history is being made from day to day. Events of the coming years may alter radically our interpretation of evidence now in our hands. But correlation of accruing data should nevertheless be a constant and continuing process; and from our facts we should strive to draw inferences which, as President Merriam has indicated, may perhaps serve to sharpen and strengthen contemporary social judgment.

The Division has assumed a heavy task. Consideration of any aspect of man's career brings difficulties of an order far greater than are inherent in any other research. And in organization of such a project one encounters a strange paradox. On the one hand, the vast increase of knowledge, and its inevitable compartmenting by specialized sciences, seems to render reassembly and comprehension well-nigh hopeless. But on the other hand, there is evident throughout the intellectual world a general trend toward unification. Synthesis is becoming, in a way, more readily attainable than ever before. In the past many facts appeared to be mutually contradictory. Modern learning, however, shows that all truths are inter-related. Chemistry and physics are striking downward to common fundamentals; zoology and botany are rapidly merging and the resultant newer biology is joining hands with the physical sciences. Similar tendencies are becoming manifest in the human field, where geography, ethnography, sociology, and psychology are constantly drawing more closely together. History and archæology, although they should more definitely be conjoined than perhaps any two of the above, have not as yet achieved a working alliance. They are not only interdependent, but both can contribute to, and learn from, all other groups. If the Division can, by bringing history and archæology together in a single field, serve to further in any way the development of a better integrated science of man, it will most amply have justified its existence.

## SECTION OF ABORIGINAL AMERICAN HISTORY

The archæological investigations which constitute the Section's major activity are being supplemented, according to a carefully worked-out program, by studies of the environment in which the Maya lived, by researches upon the modern Maya, and upon the documentary history of the post-Columbian period, all of which are designed to render more readily interpretable the necessarily fragmentary archæological record.

In the correlated undertakings just mentioned, the section has received invaluable cooperation from other departments of Carnegie Institution, from many outside agencies, and from individuals. The Department of Genetics has supported the extremely significant work of its staff member, Dr. Steggerda, on physical anthropology of the living Maya, on Yucatecan agronomy, and on various aspects of present-day Maya life; the experts of the Geophysical Laboratory have given generously of their time to forward Miss Shepard's technological studies of Southwestern and Maya ceramics; the Department of Terrestrial Magnetism has trained the Section's field men in the taking of astronomical observations for determination of the geographical location of ruins, has loaned equipment, and has checked results; the Nutrition Laboratory has made many analyses of Maya foods and Dr. Benedict has collaborated with Dr. Steggerda in publications upon the basal metabolism and the diet of the Maya; the Division of Plant Biology, by kindness of Dr. Shreve of the Desert Laboratory, has made identifications for the Chairman of plant products from ancient dwellings in Arizona and New Mexico.

The University of Michigan biological survey of Central America, carried on at its own expense, is resulting in acquirement of a great mass of information upon the zoology and botany of the Maya area. One result of this investigation is a series of botanical papers, published by the Institution under the editorship of Messrs. Bartlett and Lundell. Duke University, through Dr. Pearse and Dr. Hall, is contributing to knowledge of environment through researches upon the fauna of the inland waters of Yucatan. The United States Bureau of Plant Industry has supplied the services of Messrs. Collins and Kempton, and the United Fruit Company those of Dr. Popenoe, for the investigations upon Maya agronomy and the genetics of maize.

With the University of Chicago there has for some years been in effect an arrangement whereby members of its staff have served as half or part-time employes of the Institution. In this way the Division has benefited by the wise and energetic direction of its ethnological program by Dr. Redfield, Dean of Social Sciences in the University; and has been able to carry on a survey of the Mayan linguistic stock by Dr. Andrade. Also by a part-time arrangement, Miss Shepard, of the Laboratory of Anthropology, has worked on ceramic technology. The Peabody Museum of Harvard University and the Laboratory of Anthropology have supplied quarters to many Division investigators; and the splendid Maya libraries of the Peabody Museum and the Department of Middle American Research of Tulane University have been placed unreservedly at our disposition. Both the last-named institutions and the Museum of the University of Pennsylvania have permitted study and even publication of unique manuscripts.

Contributions by individuals have been of equal importance. Dr. G. C. Shattuck of the Harvard School of Public Health has not only donated his time for field work bearing upon problems of disease, but has assumed the expense of preparing his medical monographs on Yucatan and Guatemala for the press. Mr. Lawrence Roys has personally defrayed the cost of several trips to Yucatan to study the structural features of Maya architecture; Mr. Ralph L. Roys and Mr. Robert E. Smith, who receive purely

nominal salaries, are carrying on key investigations of post-Conquest Maya documents and of Uaxactun pottery, respectively. Lastly, Miss Lila O'Neale, of the University of California, has devoted her sabbatical year to research upon Guatemalan textiles.

Scientific activity in foreign countries naturally requires cooperation of governments concerned. In Mexico, Guatemala, and Honduras the Institution has received most effective aid from the authorities: Lic. Toro, Director of the Department of Monuments of Mexico, and Ing. Ignacio Marquina, of the Section of pre-Hispanic Monuments; Lic. Antonio Villacorta, Secretary of Public Education of Guatemala, and Sr. Carlos Villacorta, Director of the Guatemala National Museum; Dr. Jesus Rodriguez, Secretary of Public Education of Honduras, have all striven to facilitate the work of the Institution. The government of Honduras has participated actively in the excavations at Copan, defraying all costs of labor and of the transportation of supplies.

This lengthy statement of cooperations is presented here not only to express the Division's deep gratitude for effective assistance, but also to make clear the many types of relationship, both practical and intellectual, involved in prosecution of so many-faceted a program.

#### UAXACTUN—A. L. SMITH

The eleventh season at Uaxactun opened on February 29 and closed on May 30, with A. Ledyard Smith in charge, Edwin Shook acting as assistant and surveyor, Sr. Frederico Soberanis as Guatemalan Government inspector. Practically the whole season was devoted to excavations in Structure A-V, the so-called Palace. Work on this multi-chambered building was begun in the spring of 1931 and has been continued during the past four winters.<sup>1</sup>

By the close of the 1934 season the outer parts of A-V had been cleared and evidence of earlier buildings found. In 1935 some of the older construction inside the Palace was uncovered and a wide trench, cut to bedrock, was run through the north side of the building to the Buried Court. The program for 1936 called for completion of the investigation of the Palace. It was hoped to trace the various periods of construction in the Palace from the nucleus from which it started, through to its last addition. To this end two more wide trenches were cut through the building, one east and west, the other north and south. So heavy a schedule necessitated the employment of double the amount of labor used in previous years. The two large trenches, carried down to the underlying limestone, completely transected the Palace. Two excellent cross-sections of the whole structure were thus obtained, which show plainly the method by which it was gradually built up.

First, the very uneven surface of the limestone was leveled by cutting away or filling in. In some instances the rock was cut to form the lower part of a terrace wall. The earliest floors were then built. The first floor, close above bedrock, supported a low, plastered, oval platform with a step at one end. Although no post-holes were found, there can be little doubt that it once supported a house of perishable materials. On floors above this

<sup>1</sup> Statements regarding the archaeological significance of Structure A-V and accounts of earlier work are contained in Year Books Nos. 31-34.

there came to light several fragments of similar platforms, one complete example 5 feet above the bottom. It was oval in shape with a rectangular front terrace. The floor of the higher oval section was pierced by four post-holes, the terrace by two, showing definitely that it once supported a bush house. Using the original post-holes, Mr. Smith made a reconstruction of the house. Two graffiti of bush houses supported by similar platforms, from a door-jamb of one of the Period II rooms, served as a guide for the restoration.

Above the house platform the type of construction changed. The floor directly overlying it supports the earliest truncated pyramid with vaulted superstructure. Following this there is a sequence of buildings showing gradual development both in substructures and superstructures, the most marked change having been from the use of large, roughly cut stones laid horizontally, to the production of true cut-stone veneer.<sup>1</sup> The various building levels were clearly evident, and stratigraphic collections of sherds were gathered from each. These have not yet been studied, but they appear to confirm the ceramic sequence so far established for Uaxactun. It was of interest to find that polychrome wares first occur in the Palace in connection with the earliest vaulted buildings.

Much new archaeological information accrued. It was learned, for example, that the earliest terraces supporting stone buildings possessed rounded, inset corners similar in shape to those used in the next-to-last period. Another interesting discovery was of certain re-used stones, perforated and originally T-shaped. These resemble stones forming the roof decoration of a building represented in fresco in Room 37. One new buried room, one cache, two animal burials, and twenty human burials were found. The graves were of particular interest in that they were of all periods from earliest to latest, and varied greatly in construction.

The face of Stela 26, bearing the well-preserved and very early date 9.0.10.0.0, was cut from the monument and shipped in two fragments to the National Museum in Guatemala City.<sup>2</sup>

In addition to the work on the Palace, the small reservoir east of the causeway joining A- and B-groups was partly excavated, the causeway was investigated, and the ball court in B-group was uncovered. The reservoir lies about 100 feet west of the causeway. It is rectangular, measuring 42 by 48 feet, long axis east and west. In its construction the natural clay had been dug out to a depth of about 8 feet at the center and gradually sloped up to the surrounding ground level. The bottom had then been covered with a 3-inch deposit of sand supporting a complete pavement of large stone slabs. These in turn were covered by an 8-inch layer of sand. Around the edge was a row of stone slabs placed horizontally. The reservoir, in a slight hollow, obtained the drainage from the higher ground in the immediate vicinity.

A trench was dug into the west side of the causeway connecting A- and B-groups. The retaining wall was found to be so badly fallen that it was impossible to tell whether it had been vertical or sloping. The plastered

<sup>1</sup> For description of the several types of superstructure, see Year Book No. 32.

<sup>2</sup> For further information concerning Stela 26, see Year Book No. 33.

floor of the causeway was then examined. It proved to turn up to parapets approximately 3 feet high on both sides of the causeway.

The ball court in B-group, lying at the north end of the causeway, is formed by two parallel rectangular structures, their long axes north and south. The intervening space is 14 feet wide and 57 feet 6 inches long. Of the two plastered floors discovered, only the upper has so far been cleared. This turns up on either side of the court to vertical, stone veneered walls 2 feet high. From the tops of the walls terraces 13 feet wide slope upward 4 feet to meet the 3½-foot vertical veneered walls of the upper terrace, which drops down vertically on the outside to plaza level. No markers were found in the alley or on the terraces, but such may occur when the upper floor of the alley is removed. This ball court is almost identical to one investigated by the University of Pennsylvania at Piedras Negras.

The large reservoir west of B-group was bushed, and a pit dug in its north side exposed a retaining wall. Much more work will have to be done before definite results can be obtained.

#### COPAN—GUSTAV STRÓMSVIK<sup>1</sup>

The current field-season at Copan comprised the months of December 1935 to May 1936, inclusive. Mr. Gustav Stromsvik was in charge, assisted by Mr. Aubrey S. Trik. Col. Antonio Sans, representative of the Honduran Government, most efficiently and tactfully handled the employment of labor and the transportation of supplies. Principal activities were diversion of the Copan River, tunneling into the Acropolis, mapping the Acropolis, and repair of Temple 22.

Of most immediate practical importance was the turning of the Copan River away from the site. For centuries this stream, subject to violent summer floods, has been undermining and washing away large parts of the ruins. The most evident damage has been caused to the enormous central group known as the Acropolis, as is proved by early Spanish accounts and by the photographs and plans of Maudslay and the Peabody Museum made fifty and forty years ago, which show that the Acropolis formerly extended considerably farther to the south.

The problem of protecting the Acropolis was studied during the 1935 season, and it was decided to open a canal across an ox-bow bend, throwing the river, by means of a diversion dam, into this new channel. The canal was accordingly dug by Government labor under supervision of Colonel Sans in the summer of 1935.

To haul the large quantities of rock required for the dam a specially equipped dump truck was shipped by sea to Puerto Barrios, by rail to Zacapa and thence driven to Copan. No motor car had hitherto penetrated this part of Honduras and the last twenty-five miles over mountain mule trails necessitated five days of unrelenting toil. A mile of road was then built up the river to the dam-site, a loading hopper was constructed, and work was begun on the heaps of uncut stones and debris left by earlier

<sup>1</sup> A report upon the first year's work at Copan is contained in Year Book No. 34, pp. 118-120.

excavations. Some seven thousand tons of this material were thus cleared from the Court of the Hieroglyphic Stairway and put into the dam. Early in March the water was turned into the canal, but the heightening and thickening of the dam continued until the end of the season. It remains to be tested by the floods of the coming summer.

Extensive tunneling operations were conducted in the Acropolis as a first step in the study of this vast complex which, like so many Maya constructions, grew to its present size by the piling of building on building. Clear evidence that the Acropolis contains a number of accretions is offered by the cut made by the river on its eastern face, where a whole series of earlier floor levels and several sections of masonry wall have been exposed. It was therefore certain that an extensive stratigraphy of architectural remains must lie within, and it was hoped that well-preserved buildings might perhaps be found, as has been the case at Chichen Itza and at Uaxactun.

Toward the close of the last season Tunnel I was started in Mound No. 11, at the side of Stela N in the Court of the Hieroglyphic Stairway. An underlying stairway was immediately encountered, only two meters below the outer stairs. The solid adobe and stone fill of the structure rendered tunneling comparatively easy and safe. Lack of proper digging tools, however, and particularly of means for lighting and ventilating the work rendered continuation in 1935 inadvisable. This year a small electric plant was imported to supply light and, by means of fans, to insure circulation of air. Work on Tunnel I was continued, and another, Tunnel II, was opened into Mound No. 26, beside the foot of the Hieroglyphic Stairway. Tunnel I was run up the 19 steps of the buried stairway, along a low terrace and up several more steps, upon the highest of which was found an as yet undeciphered hieroglyphic inscription 2 meters long. The tunnel was driven to the very center of the mound, where the difficulty of disposing of the debris became so great that it was temporarily abandoned.

Tunnel II was dug through the talus of debris at the base of the mound, through two courses of the facing masonry of the lowest outer terrace, and into the hearting of the pyramid. The first few meters consisted of rough quarried stones set in adobe mixed with lime. Then the basal courses of an earlier pyramid were found. The faced-stone covering, if such had existed, had been removed. The fill of this older construction, contained more and purer adobe and fewer stones; the latter, for the most part water-worn boulders, were laid in regular horizontal courses between thick layers of adobe. The tunnel was continued until a cross-wall of small, roughly faced stones was encountered, some 10 meters from the outer terrace. Following up this wall toward the south, a badly defaced and chipped stucco mask panel was found, adorning the side of a low terrace. Further digging proved that the upper part of this terrace had been mostly removed before being covered over. A downward-sloping drift was then started, going under the base-courses of the terrace, in search of still earlier constructions. It was run inward and down through the above-mentioned adobe and river-boulder fill, eventually reaching a thin layer of black, sticky, earth, which contained potsherds, charcoal, and animal bones. Beneath this midden was virgin soil.

When Tunnel I had been completed, a new one, Tunnel III, was started to the east side of Stela N, and pushed straight into the mound, through the stairway followed in Tunnel I. It penetrated three superimposed stairways, eventually reaching a very flat stairway; this was followed upward in the hope of finding a hieroglyphic inscription similar to that laid bare in Trench I; the top step, however, was plain. Valuable series of potsherds and numerous small artifacts were gathered from the various levels. A pit sunk through the innermost and lowest structure found in Tunnel III, which is a low terrace under Stair No. 4, revealed several floor-levels. Virgin soil was reached at about the same depth as in Tunnel II. None of the potsherds from the pits or tunnels, even those from beneath the lowest floors, appeared to be typologically more archaic than those from the surface; the ceramic material, however, has yet to be examined by a specialist. At present it therefore seems probable that the site of the Acropolis and adjacent mounds was reclaimed from the river and the enormous mass of construction erected in a comparatively short time. To accomplish this the population of the vicinity of Copan must have been large. It seems reasonable to believe that the ancestors of the builders of the Acropolis must also have lived in the valley; some presumably on the higher land, where the remains of their settlements should have escaped destruction by the floods which seem periodically to have swept the lower-lying terrain. When these have been found, materials of great importance should accrue.

A third activity was the beginning of a detailed map of the Acropolis and adjacent structures, a project undertaken during January and February by Mr. Edwin Shook before he left for Uaxactun. Mr. Shook not only surveyed such parts of the ruins as remained uncovered by débris, but also made a number of minor excavations to determine the location of mound and plaza corners. A number of interesting sculptures were thus brought to light.

Reconstruction was confined entirely to Temple 22. This most beautiful of all Copan buildings, located on the north side of the East Court of the Main Group, has been gradually falling to pieces due to the action of vegetation and weather; and in December 1934 a heavy earthquake reduced it to a shapeless mound.

Work was begun by Mr. Trik in December by clearing away the trees and brush which were beginning to envelop the ruin. Excavation was started at the entrance of the temple. Only a few courses of the jambs were found in position, but the wall-stones were in place almost up to the spring of the vault. Although standing, the walls were leaning heavily and it was necessary to relay them in cement.

Practically all the carved stones of the sculptured decoration of the interior doorway, the outstanding feature of the building, had fallen. They had not suffered greatly and could largely be replaced in their original positions as shown in Maudslay's photographs. In reconstructing this sculpture the ancient method of supporting the stones and vault over the doorway became evident. This had involved the use of long wooden beams which fitted into specially cut stones and rested on the top course of the walls on either side of the doorway. The original beams had rotted, drop-



ping the carved stones down on the wall, and giving a deceptive appearance that the stones were *in situ*. In rebuilding this portion of the Temple, Mr. Trik used two strong mahogany beams to carry the sculpture. The only lacking stones are those which spanned the actual opening of the doorway and a few pieces from the east side. It is possible that these may be found and the restoration of the sculpture be completed by further excavation outside the temple.

Attention was next turned to the elaborate decoration on either side of the doorway. The east side of the façade was excavated, bringing to light unexpectedly large parts of the wall and of the flanking sculptures. Although the entire composition can not be restored, enough remains to show that a gigantic serpent head formed the entrance to the temple. The mosaic of carved stones on either side represents the eye and cheek elements, and breaking out from the wall on either side, is a large curling fang which rests on the upper step of the stairway. The face of the step is carved to represent the teeth of the lower jaw. The doorway, between the eyes and fangs, forms the mouth.

Few artifacts were found in Temple 22, but a great number of broken pieces of sculpture from an earlier structure occurred in the fill of the walls; practically all were painted a dark oxide red and several showed small patches of bright green plaster.

Mr. Trik devoted much time to study of the construction, plan and decoration of the building. Sketches illustrating structural methods were made, and measured drawings of the sculpture begun. From these, architectural restorations will later be prepared.

#### CHICHEN ITZA—S. G. MORLEY

Dr. Morley was in Yucatan from September 1935 to August 1936, engaged in completion of his monograph upon the inscriptions of Peten. He also devoted much time to forwarding the work of the various collateral investigations based upon Chichen: the Campeche-Quintana Roo expedition (p. 125), the ceramic-architectural survey (p. 122), the ethnological survey (p. 131), the anthropometric and other studies of Dr. Steggerda (p. 140), and the documentary research of Messrs. Roys and Rubio Mañé (p. 121). Likewise using Chichen as headquarters were an ornithological party from the University of Michigan (Dr. van Tyne and Dr. Trautman), and a biological party from Duke University (Dr. Pearce and Dr. Hall).

Dr. Morley was at Sotuta and Yaxcaba for a week in the middle of December 1935 in connection with his genealogical investigation of the former ruling houses of the Yucatan Peninsula. Sotuta was the seat of the Cocom, the ancient lords of Mayapan, during the Spanish Colonial period and additional data concerning Cocom family history were sought there. He visited X-Cacal for a week at the beginning of March, on the occasion of the festival to the Virgin of the Conception, one of the two most important events of the ceremonial year among the X-Cacal Maya. Dr. Morley's party was handsomely entertained, and in addition to strengthening the bonds of friendship already established between these semi-independent Indians and the Institution's representatives in Yucatan (upon which Mr. Villa's con-

tinued residence among this remote and highly suspicious group entirely depends), Mrs. Morley secured an exceptionally fine series of photographs of representative types of men, women and children and of the ceremonies witnessed.

J. Ignacio Rubio Mañé continued his documentary investigation under the direction of Dr. Morley and Mr. Scholes. He made occasional trips to outlying towns and villages to examine church records in connection with the study of the Xiu, Cocom and Pech families. The larger part of his time was spent in Merida, where he searched ecclesiastical, governmental and private archives for information concerning the growth of the church properties, and upon the development of the *haciendas* and their relation, if any, to the earlier *encomiendas*.

Mr. Rubio Mañé succeeded in relocating the so-called Codice Perez, which contains copies of earlier Maya manuscripts made by the eminent Yucatecan antiquarian, Don Pio Perez, about the middle of the last century, and which heretofore has been known only through the Karl Berendt copy of 1866, now in the Museum of the University of Pennsylvania, and a later copy by Ermilo Solis Alcala of Merida about a decade ago, both containing a number of errors. Perhaps the chief importance of the Codice Perez lies in the fact that it contains the only known copy of the Book of Chilam Balam of Mani, the original of which is now lost or more probably was destroyed in the War of the Castes in 1846-7. This latter, in turn, contains one of the only five chronicles of pre-Columbian Maya History that have come down to us. Permission to photograph and publish this exceedingly valuable manuscript was secured from the owner. The photographic reproduction is now being studied by Ralph Roys who will eventually undertake the preparation of an annotated translation.

Another manuscript photographed for Mr. Roys this year was loaned to Alfonso Villa at Tuzik by one of the X-Cacal Maya. This consists of two parts; a legend of a hunter and a deer; and, more important, a series of questions put to candidates for chieftainship. It is similar to the questionnaire given in the Book of Chilam Balam of Chumayel, already translated by Roys. Although the X-Cacal copy of this text was made at Santa Cruz de Bravo only 61 years ago (1875) a colophon indicates that the original from which it was copied was reduced to writing in 1628.

Karl Ruppert reached Chichen Itza on January 21. He spent the months of February and March in writing a report on his excavations of previous years at the Mercado. In April Mr. Ruppert, assisted by Mr. P. N. Fontaine as consulting architect, commenced the excavation of the small T-shaped structure just east of the large temple on the east side of the Court of the Thousand Columns. The building is of unusual groundplan, being composed of a portico with columns along the front or outer side, a smaller chamber behind, and a still smaller niche at the back where a secondary fireplace was found. The only similar construction, known at Chichen Itza, is one just south of the Caracol which was excavated by Ruppert in 1929. Interior arrangements of both buildings strongly suggest that they served as vapor baths, special buildings for which purpose—the *temezcalli*—are known to have been used by culturally not dissimilar peoples of the highlands of central Mexico in the early Sixteenth Century, and which indeed

still survive in the latter region. The excavation and repair of this building were made possible by the generosity of the Misses Amelia E. and Martha White of Cocoanut Grove, Florida.

#### THE ARCHITECTURAL SURVEY—H. E. D. POLLOCK

In last year's report<sup>1</sup> it was pointed out that the ruins of the Puuc region of Yucatan were serving as point of departure for the comparative study of the architecture of Yucatan. It was further noted that, while considerable progress had been made toward gaining a knowledge of Puuc architecture, an obvious lacuna was to be found in the lack of any adequate study of the great ruins of Uxmal. In addition, it seemed desirable that a reconnaissance be made of a number of lesser sites in the Puuc; and lastly, it was pointed out that the small amount of work done outside the area gave promise of highly significant results whenever the survey could be carried into contiguous regions.

The operations of the past season were planned in accordance with the foregoing factors. Work at Uxmal and a rapid reconnaissance of minor sites were to terminate the survey of the Puuc. Keeping in mind the work of future years, the reconnaissance was to be extended to include a number of sites in the very important Chenes region lying south of the Puuc and west of the modern city of Campeche. Necessities of transportation dictated that the Chenes trip come first, at the height of the dry season. As in past years, the architectural and ceramic surveys operated in conjunction.

While previous work had provided a considerable knowledge of the ruins of the central and northwestern sectors of the Puuc, little was known of the southeastern and southern ruins. The expedition therefore first visited Chacmultun, one of the larger southeastern sites, and thence moved westward to Chacbolai, Kom, Kiuc, and the little-known remains of Huntichmul I, all of which proved to fall definitely within the tradition of Puuc architecture. At Kiuc were found three stelæ, two plain and one with the crude carving of a skeleton; and at Huntichmul I a façade decoration that is common in the Chenes and further south.

The next move was southward to Itsimte. These ruins are very extensive, but due to their proximity to the town of Bolonchenticul they have been so thoroughly robbed of building stone that few architectural details remain visible. Geographically, the site is located in a region that might be expected to form the southern border of the Puuc area, and what little may be gleaned from the architecture seems to be in accordance with expectation, for the remains appear to be essentially Puuc in character, but with certain transitional, or at least exotic, elements not usually associated with the ruins to the north. While the reconnaissance left the Puuc at this point, it subsequently visited two ruins that appear further to delimit the region and thus may be mentioned here. These are Xkichmook and Xculoc, the former lying east of Itsimte, the latter northwest. Like Itsimte, both seem to contain transitional architectural elements, Xkichmook probably drawing from the Chenes area to the south, Xculoc being rather definitely associated with the nearby Xcalumkin region which in turn seems closely related to the Puuc.

<sup>1</sup> Year Book No. 34, pp. 124-126.

Leaving Bolonchenticul and Itsimte, the party moved southeastward to Xtampak, more frequently known as Santa Rosa Xlabpak. These ruins are definitely non-Puuc, and presumably are to be associated with the as yet ill-defined geographical and cultural area known as the Chenes. Xtampak is of great importance. Not only is there a large amount of readily available architectural detail, but during the present season eight stelæ were discovered, two of which carry Initial Series that record dates a year or two prior to the katun-ending 9.16.0.0.0. The style of architecture at Xtampak has been used in support of one of the proposed correlation of Maya and Christian chronology, so the occurrence there of dated monuments may prove of value in dealing with the vexed correlation problem as well as in fixing the relative chronological position of a distinctive style of architecture.

With one exception the remaining ruins visited were in the Chenes area. In the regions of Hopelchen, Dzibalchen, and Iturbide are a number of remains varying considerably in size and importance. Those examined were Dsehkabtun, Nocuchich, Dzibilnocac, Nohcacab II (or IV), Chenchan (Chanchen), Tabasqueño, Dsibiltun, and Hochob. The last two are worthy of particular mention. Hochob, the southernmost point reached, offers a wealth of splendidly preserved architectural detail which, stylistically, is probably further removed from the decoration of the Puuc than is that of any other site visited. They may prove to be typical of the Chenes, or may be transitional to another school of architecture farther to the south. Dsibiltun, near the village of Komchen in the heart of the Chenes country, exhibits a form of architecture that appears not only to be entirely Puuc in tradition but of a highly developed and presumably late stage. If the above-suggested cultural and chronological associations are correct, the site is obviously of great importance.

Lastly, the reconnaissance included Etzna-Tixmucuy, some distance west of the Hopelchen-Dzibalchen region. While Etzna was probably one of the great cities of the Yucatan peninsula, it is unfortunately so ruinous that it offers few architectural data, although further exploration may remedy this defect. What could be gathered from a single structure indicated that the remains are more closely allied to the Xcalumkin-Puuc group than to the Chenes, and that they might quite possibly have influenced Puuc development. The chronological position at present assigned to Etzna rests more upon the relatively early dates of its stelæ than upon its architecture, although the latter corroborates the inscriptions by appearing definitely earlier than the characteristic Puuc forms.

The work at Uxmal was largely confined to the smaller and lesser-known structures. Of outstanding importance is the existence of several buildings that in mode of construction or style of decoration seem surely to be allied to the remains of the Chenes. Two of these give evidence of being demonstrably earlier than the structures known as the Casa del Gobernador and the Casa de las Tortugas, but in so far as the Gobernador and Tortugas probably are comparatively late examples of Puuc architecture, the determination of the relative chronological position of the Puuc and Chenes styles is not greatly aided. It is worthy of note, however, that should we

subscribe to the rather common view that the Chenes remains antedate those of the Puuc, a long period of occupation is indicated for Uxmal. "

In judging the progress of the survey, it seems that the architecture of the Puuc has now been sampled adequately and that activity in that region may for the present be discontinued. The work of the past season greatly enlarged the survey's horizon, in that for the first time a considerable number of ruins outside the Puuc were visited. As a result, local culture areas are now beginning to take shape. There are indications, moreover, of interinfluence between areas, and suggestions as to relative chronology. Thus, we find that the Chenes culture penetrated to Uxmal, while the Puuc tradition was carried to Dsibiltun. It is becoming increasingly clear that certain existing ideas in regard to conditions in the western part of the peninsula must be revised. The different architectural styles and the local cultures that these styles reflect can no longer be thought of as sequent stages in the passage of a single cultural impulse from south to north, each stage marking an advance in time. On the contrary, they must be considered as products of several impulses that may have varied widely in point of origin. It is possible, in fact probable, that difference in origin, rather than difference in time, was the major factor in bringing about the observed variation in the character of the remains.

Problems relating to the course of future work have been clarified. In earlier years Etzna, Holactun-Xcalumkin, Oxkintok, and possibly Jaina had been marked out as of strategic importance in the western Yucatan-Campeche area. To these must now be added Xtampak, and probably Dsibiltun. The reconnaissance of the Chenes, moreover, has demonstrated the need for its fuller investigation and for exploration in several adjacent regions. South of Hochob there is a strip of archæologically little-known territory that lies between the area traversed by the past season's reconnaissance and that covered by the Division's several Campeche Expeditions.<sup>1</sup> In so far as much of the architecture of southern Campeche and southwestern Quintana Roo seems allied to that of the Chenes, it is important that the remains of the intervening area be better known. The work at Xcalumkin and the brief visit to Etzna indicate that the ruins in western Campeche differ in style from those of the Chenes. The architecture of these western sites is closely related to that of the Puuc and in conjunction with several relatively early Initial Series dates, suggests that the region formed the avenue of approach for many of the basic traits of Puuc architecture. Almost no remains are known between Etzna and Xcalumkin, although ruins are reported by the natives. This is an area in which one may look forward with some confidence to the recovery of hieroglyphic material, and there is little doubt that further work here will amply justify itself. Nor should the southwestern extension of this coastal region be neglected. South of Etzna and Champoton, and west of the area covered by the Campeche Expeditions is a blank spot upon the archæological map. And as the Etzna-Xcalumkin-Puuc complex does not seem to find direct derivation either from the Chenes remains or from those of the Peten, southwestern Campeche is the logical place to seek earlier links in that cultural chain. The region, moreover,

<sup>1</sup> See Year Books Nos. 31, pp. 95-96; 32, pp. 89-92; 33, pp. 93-95.

appears to have included the ancient *cacicazgo* of Acalan-Tixchel,<sup>1</sup> the history of which forms the subject of a monograph now in preparation by Messrs. Scholes and Roys, and Miss Adams, and it is not beyond hope that some connection may be established between the archæological remains and the documentary records. This would obviously be of great importance for the reconstruction of Maya history.

EXPLORATION IN CAMPECHE AND QUITANA ROO AND EXCAVATIONS  
AT SAN JOSE, BRITISH HONDURAS—J. E. THOMPSON

In an endeavor to learn something of the archæology of the region directly east of that explored by the Campeche expedition of 1932, 1933, and 1934,<sup>2</sup> an expedition left Chichen Itza at the end of February 1936, with Mr. Thompson in charge, Mr. J. C. Harrington surveyor; Mr. Conrad Kratz made rubbings of inscriptions and graffiti. Principal objectives were the collection of epigraphic material and of such other data as might throw light on the position in Maya history of the peculiar architectural styles known as Rio Bec and Ramonal, both of which find very close parallels in the architecture of the Chenes region, and to a lesser extent in that of the Puuc and that of the so-called Renaissance style at Chichen Itza and elsewhere. On the other hand, there are also certain parallels between Rio Bec sites and cities of northeastern Peten, particularly La Honradez. On the strength of the above resemblances it has been suggested that Rio Bec and Ramonal architectural styles are transitional in time between the so-called Old and New Empires. An alternative theory that the sites are transitional merely in a geographical sense has also been advanced.

Three new sites, Las Escobas (18° 21'6, 89° 20'6), No Te Metas, and San Lorenzo, possessing architecture in these two styles, were discovered. Unfortunately very little ceramic material was recovered. Sherds from under the floors of the buildings would undoubtedly have solved the problem. A few sherds, however, were found at terrace edges, and these should eventually yield evidence on the age and cultural relationships of the ruins. A considerable amount of information on architecture and masonry was obtained.

El Palmar, a large site situated at 18° 5'0, 89° 20'0, detained the expedition for three weeks. This city had been built around two lakes, one of which had in its center a small island bearing the ruins of a small structure and a plain stela. Mr. Harrington mapped an area 900 meters north and south, by 660 meters east and west.

Every superstructure had fallen, but fragmentary walls showed that the masonry was unsquared and unfaced. It had been laid in and covered by masses of mortar. This masonry contrasted sharply with the very carefully faced stone veneer found on buildings of the Rio Bec and Ramonal styles. The collapsed state of the superstructures of El Palmar is probably due to inferiority of construction, since the large areas of exposed mortar offer ready lodgment for vegetation. Forty-four stelæ and several round

<sup>1</sup> See Year Book No. 34, p. 147.

<sup>2</sup> See Year Books No. 31, 95-96; No. 32, 89-92; No. 33, 93-95.

altars were found at El Palmar, but owing to the extreme softness of the limestone from which they had been hewn, and the very low relief, little carving was preserved. Twenty-three stelæ were carved, five plain, and sixteen so weathered that it was not possible to say whether or not they had once been sculptured. A peculiar feature of the inscriptions was the apparent absence of Initial Series. In those cases in which glyphs were legible, there were certainly no Initial Series, while in all other cases glyph blocks were too few to have recorded dates by this method. Period ending dates recovered were: 9.14.0.0.0?; 9.14.10.0.0; 9.18.10.0.0; 9.19.10.0.0; 10.2.15.0.0??. The stelæ can be grouped stylistically with those of Naranjo and Calakmul, but in composition one stela, at least, resembles those of La Honradez, in that the base of the design is occupied by a large mask, perhaps a link with the carved square columns of Yucatan.

Artistically, a find of outstanding importance was a cache of eccentric flints and obsidian cores and flakes from beneath a stela. One of the flints, which was executed in the same technique as some found at Quirigua,<sup>1</sup> was superbly chipped to represent, in profile, four seated deities.

A ball court, situated close to the great plaza, is of the usual early type with sloping sides. Two of the pyramidal substructures were of very considerable elevation: 119 and 142 feet, respectively, above the level of the aguada.

\* During the visit to El Palmar a new and very simple method of recording epigraphic material was evolved: the photographing in direct light of Chinese ink rubbings in position over the glyph blocks. This does away with the inevitable distortion produced when the paper sheets bearing the rubbings are removed and laid flat. The El Palmar rubbings, together with photographs of the glyph blocks taken with side lighting, constitute an epigraphic record such as exists for few Maya cities.

A stratification of pottery was encountered at El Palmar, sherds of a phase characterized by basal flanged bowls being found underlying a phase in which the lateral ridged bowl predominates. The earlier phase can be correlated in form with the Tzakol phase at Uaxactun, Holmul III (and perhaps earlier Holmul), and San Jose II. The later phase at El Palmar can be correlated, so far as dominant form is concerned, with San Jose III, which in turn appears to have been contemporaneous with Holmul V and the Tepeu phase at Uaxactun. With the earlier pottery at El Palmar were mixed a few sherds indicating a yet earlier ceramic development, with forms partially corresponding to the Chicanel phase at Uaxactun and early pottery at San Jose. On the whole El Palmar pottery seemed closer to that of British Honduras than to that of the Peten.

In the course of the field work attempt was made to collect simple botanical data. Since botanical expeditions in the Peten and contiguous areas are likely to cover far less ground than the more frequent archaeological parties, the archaeologist may have to depend largely on his own observations for information on such vegetational changes as may have a bearing on cultural subdivisions of the Maya area. Naturally, the archaeologist has, as a

<sup>1</sup> T. A. Joyce, *The Eccentric Flints of Central America*. J. R. A. I., LXII and Year Book, 1933, 88.

rule, neither the time nor the training for a thorough botanical survey, but many important trees are easily recognizable, and their distributions may have archæological importance. With this in mind, notes were kept on such features of the flora as could be observed along the trail. It was possible to note gradual changes in the vegetation as one progressed westward. For example, no cohune palms were noted until within 15 to 20 miles of the Rio Hondo. Similarly the all-spice tree was entirely absent in the western section, but gradually became abundant as one traversed Quintana Roo. A great belt of cordoncillo, escoba and bay-leaf palm extends from north to south, its western edge roughly coinciding with the Quintana Roo-Campeche border. Within this belt most of the Rio Bec and Ramonal sites appear to be situated.

At the conclusion of the work at El Palmar, Mr. Kratz returned with surplus equipment to Yucatan via Campeche, while Messrs. Thompson and Harrington proceeded via Chicchanha to Botes on the Rio Hondo, and thence via Payo Obispo to Corozal in British Honduras.

From Corozal, Messrs. Thompson and Harrington proceeded to San Jose, where Mr. Thompson had carried on excavations in 1931 and 1934.<sup>1</sup> Previous stratigraphic work at San Jose had revealed a sequence of five ceramic phases, which strongly suggested that the site had continued to be occupied after the supposed abandonment of the Central Maya area (shortly after 10.3.0.0.0), and that in all probability it was not deserted until the period of Mexican contact in Yucatan. The purpose of the present season's work was to amplify the ceramic and architectural information already yielded by this site, and to seek answers to certain problems which had arisen in preparation of the report upon the earlier excavations.

In the three weeks spent at San Jose a considerable quantity of ceramic material was obtained. cursory examination of this suggests that three new ceramic phases may have been established: by a division of the original San Jose I phase into two phases corresponding to the Mamón and Chicanel phases at Uaxactun;<sup>2</sup> the third, a transitional phase between San Jose III and IV, was only sparingly encountered in 1934, but the finds of the present season suggest that it may have to be elevated to the rank of an independent ceramic phase.

Little material of the San Jose II<sup>3</sup> phase was encountered. This was regrettable as it had been hoped that more light might be thrown on the Teotihuacanoid form which occurs in this phase. The 1936 excavations, however, produced additional evidence of the far-flung trade relationships of the site during San Jose V. New examples of Yucatecan slate ware ollas, marble vase fragments and another spindle whorl, decorated with *chapopote* designs in Huastec style, were found associated with this phase. The presence of such importations, as well as of carved slate (one example), an apparently early simple silhouette form of orange ware (one example), many finds of carved red ware, and one of copper, together with total absence of

<sup>1</sup> Year Book No. 33, 95-98.

<sup>2</sup> Robert E. Smith, *Preliminary Shape Analysis of Uaxactun Pottery*.

<sup>3</sup> By a regrettable oversight this phase was correlated in Year Book No. 33 with the Uaxactun I phase, whereas the correlation is with Uaxactun II (Tzakol phase), both phases having the basal flanged bowl as the most typical form.



plumbate and carved orange ware, suggest that San Jose was abandoned shortly before the Mexican period in Yucatan, but at a time considerably subsequent to 10.3.0.0.0, if San Jose IV and the transitional phase following it have been correctly placed at the close of Cycle 9.

Particular attention was paid to the masonry of San Jose. Two definite types were identified and placed in chronological order by means of associated pottery. Details, such as the use of small potsherds and obsidian fragments in mortar, were observed, and a series of photographs of small surfaces of walls was made. Finally, there was excavated a very long and narrow building of a type not hitherto described for the Maya area. This structure, over 36 meters long, yet under 4 meters wide, consists of two rooms, each provided with but one doorway.

#### ZACUALPA—R. WAUCHOPE

Investigations at Zacualpa, in the Department of Quiché, were carried on by Mr. Wauchope from November 27, 1935, to March 5, 1936. Mr. A. L. Smith and Dr. Ricketson accompanied him on preliminary trips to Zacualpa early in November and the Chairman spent two weeks there in February.

The excavations were undertaken at the suggestion of Dr. S. K. Lothrop, who visited the place in 1933, and who has in press a publication on the results of his study of collections made by "pot-hunters" in this and other parts of the Department. The most significant of the pottery and artifacts described by Dr. Lothrop are believed to have come from two tombs at Zacualpa. It was hoped that additional material would be obtained through excavation. The project fell in line, also, with the Division's general program for an archaeological survey of the Guatemala highlands.

The season's work consisted of: (1) Excavation of Group C, an assemblage of low mounds located on the terrace thought by Dr. Lothrop to have contained the looted tombs; (2) excavation of a pottery-yielding section of the *barranca* which cuts into the north margin of Group A; (3) the drawing of a plane-table map of all mounds in that part of the Zacualpa valley known as La Vega. During his two-weeks' visit, the Chairman made further examination of the *barranca*, excavated a cache of vessels in a low terrace between Groups A and C, recorded all artifacts for the forthcoming publication on Zacualpa, and collected surface sherds from mounds in the vicinity of La Vega. On their preliminary visit to Zacualpa, Messrs. Smith and Wauchope mapped a small group of mounds on the plateau across the river west of the modern town. In April Mrs. Ricketson began a study of the ceramic material recovered.

Group C lies on a terrace near the southwestern margin of the valley; it comprises several long, low, rectangular mounds surrounding a small plaza. Three of these were excavated.

C-I, at the north corner of the terrace, exhibited five periods of growth. The first construction in C-I was probably the earliest in Group C, for the assemblage of its three small platform substructures and the manner in which rubbish had accumulated around them, indicate that they formed an independent nucleus from which the group of mounds later developed. Al-

though the pottery has not yet been fully studied, the apparent absence of plumbate ware and animal-head legs from the first three periods of C-I, and their occurrence in all phases of the other mounds, confirm the architectural evidence. The outstanding pieces found in this mound were a large polychrome jar containing a cremation and some finely carved bones; a large incensario with spiked rim, twisted handles, traces of blue paint, and a well-modeled human head with applied necklace, earplugs, and forehead decoration of intertwined serpents.

From the general appearance of the pottery, artifacts, and building construction of C-I, it seems likely that the platforms were for ceremonial use, while a series of adjacent rooms, which presented corresponding periods of occupation, were residential. The unit may have been the home of a person of consequence for it was more pretentious than the average house-mound and was advantageously located not far from the three main ceremonial centers of the city.

C-II, at the west corner of the terrace, also presented five periods of development. This mound again afforded excellent opportunity for stratigraphic study and yielded a far richer collection of ceramic material. The deposits of the earlier periods were marked by thick charcoal-bearing rubbish deposits, while those of later periods contained five cremations, four of which had been deposited in jars. These conditions suggest that C-II in its earlier stages was a house site with rubbish dump, which was burned and subsequently used as a crematory cemetery. The late intrusive cremation at C-I was probably contemporaneous.

The ceramic material from C-II presents a few outstanding features: abundance of plumbate ware of several types, and of a finely (tuff?) tempered orange ware; several types of animal-head legs of the rattle type, probably mold made; fragments of two perforated incensarios and two painted jars, one of which bears a design recalling the dragon motif of Coelá, Panama.

C-III, facing the plaza from the southeast, had been much damaged by "pot-hunters"; four periods, however, could still be identified. Features of this mound were a looted tomb with walls of stone masonry; stone pavement and well-constructed terraces of stone on the northwest side; three large terrace postholes, in one of which the point of a mainpost was still preserved; clay floor-drains and a stone sub-terrace gutter, the latter graded and with a right-angle turn toward the plaza; a large unslipped brown ware jar containing several pounds of clay prepared for potting. C-III yielded, in addition, ten complete vessels, five burials and four cremations.

Two interesting architectural features were common to the three mounds in Group C: adobe clay floors and wall plaster thoroughly burnt to a brick-red color; multiple pits in the adobe-clay floors. The function of the pits is unknown.

All cremations at Group C post-dated the inhumations.

The collection of artifacts from Group C is featured by an abundance of chipped obsidian points, obsidian flake-knives, polished green stone celts, clay firedogs, manos, and metates. Examples of other types of artifacts characteristic of the Guatemala highlands were perforated stone hammers

or digging-stick weights, green stone figurines, jadeite beads, a corrugated bark beater, worked sherds and sherd spindle-whorls. Set side by side in the clay plaza floor between C-I and C-II were a human figure of stone and a clay tiger head.

Among the objects from the *barranca* at Group A were about forty complete vessels, a dozen green stone figurines, many jadeite beads, and two clay earplugs. The *barranca* pottery together with twelve vessels removed from two caches half-way between Groups A and C was quite distinct from that of Group C, the absence of plumbate ware, finely (tuff?) tempered orange wares, and animal-head legs, and the occurrence of certain Peten-like shapes and painted decorations suggesting the probability that it was older. Although few traces of bones were found in either of the two latter excavations, it is probable that they were grave caches.

A type of pottery common to all three localities and found on the surface throughout the valley is the "duck pot," a curious inverted vessel-shaped object with a handle and animal head at the top.

Our present knowledge of Guatemala highland archæology does not permit very definite conclusions regarding the excavations at Zacualpa. There is as yet so little to which the Zacualpa material may be compared or to which it may be contrasted, that we must be content to regard the season's investigation as part of the groundwork on which future conclusions are to be based. In general the pottery gives an impression of lateness, with foreign affiliations chiefly southern. Plumbate ware, the Coclé-like design already mentioned, and small bowls supported on three tall legs reminiscent of Costa Rican forms, are among the outstanding examples to be cited.

Certain forms, however, resemble pottery from Teotihuacan, while bowls with basal flange and one polychrome sherd from the *barranca* seem to indicate that Peten influence was also felt during an earlier period at Zacualpa. Figurines were scarce, "Archaic" forms apparently absent, and with the exception of red-on-buff scroll-decorated bowls, the painted wares were probably all importations. The general run of paste and slip was inferior. The only other decorative feature that seems typical of Zacualpa, and this only at the *barranca* and the mid-valley caches, consists of shallow vertical flutings often found in sets of three or four on the sides of shallow, straight-sided, dark brown and black ware bowls. To the above characteristic ceramic features should be added the particularly well-molded animal-head legs of Group C.

#### KAMINALJUYU—A. V. KIDDER, O. G. RICKETSON

To the great aggregation of mounds on Finca Arevalo, Finca Miraflores and other farms in the outskirts of Guatemala City, the above name has been given by the Sociedad de Geografía e Historia of Guatemala. At the suggestion of Lic. Antonio Villacorta, Minister of Public Education, excavations were undertaken at one of these mounds. The structure proved to consist of four small pyramids built one over the other, the innermost and the second of adobe, the third and fourth of tufa blocks laid in mud mortar.

The eastern half of the complex was excavated, the operation yielding valuable architectural and ceramic data. Three tombs were also discovered,

large rectangular pits lying immediately to the east of the mound. They contained the skeletons of persons of importance, accompanied by lavish offerings of implements, pottery, and jadeite ornaments. Some of the pottery appears to bear close resemblance to that of Uaxactun, some to that of Teotihuacan in Mexico. Final description of the pyramids and conclusions regarding the cultural relationships of the associated tomb material must await excavations planned for 1937, when, it is hoped, the remainder of the mound may be cleared and a fourth tomb, believed to lie below the second pyramid, may be investigated. An illustrated preliminary report has been issued as a press-release of the Institution.

Mrs. Ricketson carried on studies of the early pottery collected in 1935 at the Finca Miraflores.

ETHNOLOGICAL AND SOCIOLOGICAL RESEARCH—R. REDFIELD, S. TAX,  
A. T. HANSEN, A. VILLA

The field workers of this group are making studies of a number of present-day Indian and mixed-blood peoples of the Maya area with reference to two projects, one in Yucatan, the other in Guatemala.

The method and the objectives of the Yucatan project have been outlined in previous reports.<sup>1</sup> Of the four communities which it was planned to investigate and compare, one still remained to be studied at the end of 1935: a village of those Maya who live between Ascension Bay and Lake Chichankanab. These Indians have remained isolated and politically independent since the War of the Castes; they are the last tribally organized Maya in Yucatan. Of the three sub-groups into which they are divided, the middle group, centering around the shrine-village of X-Cacal, was selected for study, because it is the least influenced by changes in recent years. The natives of these villages still refuse to admit school teachers or other representatives of the Mexican government.

Due to the contacts made by Mr. Villa in his trips of reconnaissance in 1932 and 1933, and to the tactful handling of Indians from these southern villages by Dr. Morley at Chichen, Villa and his wife were able, at the close of 1935, to establish themselves in Tusik, a village near X-Cacal, in a house built specially for them by the Indians. The difficulties of carrying on ethnological work were great: the uneasiness of the Indians and their hostility to all representatives of the government; fresh developments tending to open the territory to schools, roads and direct Mexican governmental control; the uncertainties of the chicle situation. Nevertheless, Villa was able to maintain relations of trust and cordiality with the people and to secure important information, much of which will, in a short time, become forever unavailable. He made a complete census and canvass of households, indicating origin and kinship connections of all persons, for the entire group of 723 persons, living in nine settlements. He witnessed and made notes on all the principal agricultural ceremonies and obtained data on many other aspects of the culture.

<sup>1</sup> See Year Books Nos. 29-34, inclusive.

A striking feature is the political-social-religious organization. The five "companies" into which the sub-tribe is divided are autonomous, except in tribal affairs. Each individual is responsible only to the chief of his own company. Membership is transmitted in the male line; the companies tend to be exogamous; a woman becomes a member of her husband's company. At the annual ceremony celebrated by the entire group at the capital village all the members of each company, whether residents of one settlement or of another, are quartered together in a single structure maintained for them only. Leadership of the entire sub-tribal group is provided by the dominant company chief and a supreme religious functionary, who carries on the ritual attending the adoration of a miraculous "talking" cross. The ties of company to company and of the individual to his "state" are at once political, military, and religious.

Mr. Villa observed and studied most of the agricultural ceremonies. Many of his notes on the religious beliefs and practises have been sent to Dr. Redfield, who will begin in July of 1936 the preparation of the comparative summary account of the four cultures and communities studied, taking advantage of these new materials from Quintana Roo, and placing them beside materials earlier collected in Merida (the city), in Dzitas (a town of mixed bloods), and in Chan Kom (a peasant village of Maya).

As was to be expected, some elements of aboriginal culture survive in the Quintana Roo villages, but not in Chan Kom or Dzitas. Such for example, are dual military-religious life-long chieftainship; a ceremony in which is erected a yaxche tree surmounted by a clown impersonating a coati; and the use of special structures to serve as lounging places for the men of each company. But it turns out to be equally true that there persist in these remote villages elements of Catholic ritual that are not practised in towns and villages nearer Merida. In spite of the strong pagan character of much of the culture, the people are familiar with the principal prayers of Catholic liturgy, observe Catholic ceremonies almost daily, recognize the distinction between High and Low Mass, observe Lent, Holy Week and several saints' days, make a special Communion bread and a special Communion liquor of honey and water, and practise lustrative penance by approaching a shrine on their knees. It is fair to say that these Indians are, in respect to the forms of worship, at once more pagan and more Catholic than are the people of the other communities studied. Furthermore, the Christian and pagan elements are more closely fused into a single cult than is the case in Chan Kom. It appears that in their isolation of many generations, the mode of living, as remade by missionary and conqueror, has "shaken down" into a completely integrated single mode of living. This is true, of course, in Chan Kom, but it is less true there, and progressively still less true in the town and the city. The summary volume upon which Dr. Redfield is now engaged will trace the changes in and disorganization of the integrated folk culture, of mixed antecedents, which grew up in the isolated villages in the centuries following the Conquest.

During the summer, Dr. Hansen resumed work, temporarily interrupted by teaching duties, on the preparation of an account of culture and civiliza-

tion in the city of Merida, which is expected to be ready for publication before the end of 1937.

The first season (1934-35) of work in Guatemala established the Highland *municipios*<sup>1</sup> as promising, if not unique, repositories of crucial data for the solution of such sociological problems as the interrelations of geography, history, and culture, the formation of castes and classes, the influence of one culture on another, the differential effects on individuals of slightly differing social frameworks. That season centered on Chichicastenango, a populous municipio, the Indian inhabitants of which live scattered on their farms, coming together on occasions to the central town which is otherwise almost depopulated except for a group of *ladino* (mixed-blood) middlemen.

It was proposed this year to study, for comparative purposes, a municipio as different as possible, in these objective features, from Chichicastenango, yet historically close enough to assure a common cultural background. To that end the field season of 1935-36 was spent by Dr. and Mrs. Tax in studying the villages of Lake Atitlan.

Lake Atitlan is not large (its greatest diameter less than a dozen miles) but its circumference is divided among no less than eleven municipios, ten of which have their principal town near the shore of the lake. The languages of the lake towns (and of Chichicastenango as well) are closely akin. The general culture, likewise—types of food, houses, and garments, political and religious organization, general economic basis and mode of life—differs but in detail from a general pattern. Such basic homogeneity one would expect from the geographic proximity; but in at least one respect—of sociological significance—the similarity could hardly have been predicted. Noting last year the lack of communal life in Chichicastenango, and the paucity there of intimate social relations, it would have been expected that, on the contrary, in these small lake towns (with as little as fifty or a hundred houses in all, and these crowded one almost on the other) communal participation and personal social relations would be strong and frequent. This is far from being the case, however. It appears likely now that there is in Guatemala a tradition of individualism and formalism so strong that it survives in seemingly the most adverse conditions. What is most remarkable at the lake, however, is not the fundamental sameness of the cultures but, considering that some of the towns are not a mile apart, in fact are in plain sight of each other, the extent to which they differ from each other—marked linguistic differences, consistent dissimilarities in family organization, in ceremonial life, in manners and etiquette, in morals and in morale, in kinship classifications, in land systems, standards of living and economic pursuits.

Striking differences in a setting as small and as self-contained as Lake Atitlan are certain to be spectacular. Also, they call for ready explanations. The difficulties involved, however, may be illustrated by differences in means of subsistence, which are usually tied more firmly to causes than

<sup>1</sup> A municipio in highland Guatemala is a political unit more or less resembling a county, but at the same time an ethnic unit, the population of which is most comparable to a "tribe," with its own costume, culture, and identity. Each municipio has at least one "town," like a county seat.

are the others. Some of the economic differences are, indeed, attributable directly to geography. But the drastic limitations, as well, of this factor in history are conspicuously displayed here.

Panajachel, for example, the only town making a specialty, and this to the virtual exclusion of all else, of intensive commercial gardening, has a river that makes irrigation practicable. On the other hand, the town of Santa Catarina makes a specialty of fishing and crab-fishing in the lake, but the inhabitants of neighboring San Antonio (agriculturalists exclusively) with the lake at their doorsteps, are known to pass their lives, ignorant of swimming and canoeing, without ever venturing on its surface. Santiago Atitlan, located strategically in an opening to the Coast, specializes in the transport of goods between Coast and Highlands; but to the villagers of San Lucas, even better located, commerce of this kind is "not the custom." San Pedro has most of the *maguery* (valued for the fiber of its leaves) that grows in the neighborhood, but the Pedranos—themselves cultivating corn and chick-peas—do little with it industrially; rather, they sell it to the people of San Pablo, who employ themselves almost exclusively to turning it into rope and hammocks.

Nine of the ten lake towns occupied about four months of the field season; the tenth town, Panajachel, was chosen to be studied intensively, and almost four months were thus spent. Researches in Panajachel need hardly be mentioned at this time apart from their bearing on the general study except to say that the problem, first suggested in Chichicastenango, of the races or social classes, was amended by the work in Panajachel. It now appears that there are not two classes, but three: Indians, working-class ladinos, and middle-class ladinos—the first two differing racially but both laborers and farmers, typically poor, rural, illiterate; the latter wealthy bourgeois, typically urban, well dressed, educated. Needless to say, the history of and the relations between the three classes in Panajachel demand comparative material from towns in Guatemala where one or more of the classes is living under different conditions. Meanwhile, it now appears desirable to divide the next field-season between Panajachel (and the other towns of Lake Atitlan) and Chichicastenango; studies in neither region are yet completed, and each may be expected to throw more light on the other. At the same time, it is planned to continue to undertake, each year, short reconnaissance surveys into territory still unvisited.

#### LINGUISTIC INVESTIGATIONS—MANUEL J. ANDRADE

In the winter of 1936 the linguistic survey of Guatemala included the villages surrounding Lake Atitlan, and the Pokomam-speaking population of Mixco, Chinautlá, and Palin in the vicinity of Guatemala City. Most of the field trip was devoted to the localities around Lake Atitlan.

According to the linguistic maps available, three languages are spoken on the shores of Lake Atitlan: Cakchiquel, Tzutuhil, and Quiche. The results of the survey, however, show that no Quiche is spoken in any of the villages surveyed. The localities where our material was collected are Panajachel, Santa Catarina Palopo, San Antonio Palopo, San Lucas Tolimán, Cerro de Oro, Santiago Atitlan, San Pedro, San Juan, San Pablo, San

Marcos, and Santa Cruz. The differences of speech among these localities are roughly proportionate to their geographical proximity. Cerro de Oro constitutes a special exception due to the fact that it was founded about two generations ago by Cakchiquel-speaking people who came from Patzitzia. There is also a rather sharp distinction between San Antonio Palopo, where the language is definitely Cakchiquel, and San Lucas Toliman, where one of the variants classified as Tzutuhil is spoken. On the other hand, it is difficult to decide whether the speech of San Pablo on the northwestern shore is Cakchiquel or Tzutuhil. With respect to this village, we can not say at present whether we are dealing with a Cakchiquel dialect which has been deeply modified by the influence of Tzutuhil, whether it is a Tzutuhil dialect modified by Cakchiquel, or whether its speech represents an older language or dialect spoken previous to the differentiation between Tzutuhil and Cakchiquel. A careful analysis of the material collected and additional data to be collected in the future may or may not decide which of these three hypotheses is tenable, but for the present we can not venture even a conjecture. What can confidently be asserted about the localities surveyed is that the speech of any one of them differs from that of any other to the extent that the differences are evident even in data which can be collected in two or three hours. And it should be noted that we do not refer merely to differences of pronunciation. No two of the villages cited have identical series of personal pronouns, for example, and in two contiguous localities the names of such common animals as cat and pig are of different provenance in some instances. In Panajachel, Santa Catarina, and San Antonio, three contiguous localities on the northeastern shore, the word for "fish" has nothing in common with the word used in the rest of the places visited, nor is it conceivable in the light of our present knowledge of the Maya languages that the two words can be cognate.

In so far as diversity of speech is concerned, a similar situation was disclosed in the three Pokomam localities investigated. In the town of Mixco itself very few individuals speak Pokomam, Spanish having largely replaced the aboriginal speech. That is not the case in Chinautla. There are differences between the Pokomam of these two localities, but they are negligible as compared with the Pokomam of Palin. Here we find again the general correlation between speech similarities and geographical proximity which is true for most of the places thus far covered by our survey of Guatemala. The Pokomam of Palin differs less from Mam than that of Chinautla and Mixco. Whether the speech of the last two localities is similar to that of the Cakchiquel villages near them we do not know. Those Cakchiquel villages have not been investigated, and, in view of the prevalence of diversity within the Cakchiquel region around Lake Atitlan, we can not venture to draw any conclusion on the basis of the material available.

The situation portrayed here is in agreement with that observable at the border line between Quiche and Cakchiquel, as stated in our report for 1934-35. The local diversities suggest the need of detailed research before the names of the languages on our linguistic maps can have any precise significance. A comparative study of the languages of Guatemala can not be guided by the maps. An investigator who decides to write a descrip-



tion of Cakchiquel, for example, can not limit his research to any particular locality within the area assigned to this language on the maps. If he does so, he can not claim that he is describing the Cakchiquel language. Some of the facts he presents may be verifiable for the whole Cakchiquel region, it is true, but many others may be observable only in the locality he studied.

In still another respect one can not be guided by the linguistic maps of Guatemala. For obvious reasons, historical facts have been taken into account in the delimitation of the various languages. The conventional distinction between languages and dialects is as misleading here as it has always been in Europe to anyone who is not acquainted with the linguistic facts. For example, Spanish and Portuguese are considered as being two languages, and not two related dialects, while Sicilian occupies the rank of dialect with respect to standard Italian. On the basis of purely linguistic criteria, either Spanish and Portuguese are two Romance dialects or Sicilian should be classified as a language. The linguistic atlases of Europe based on detailed research reveal the arbitrariness of dialectical delimitations as conceived in the past. Cultural and political considerations are irrelevant in the proper application of the terms "language" and "dialect." With regard to Guatemala, it is quite evident that if Tzutuhil and Cakchiquel are regarded as two languages, there may be many more languages in the Maya area than our traditional delimitations reveal. It is quite probable that the Maya of San Antonio, British Honduras, differs more from that of the northern portion of that colony than Tzutuhil does from Cakchiquel. Also, according to several informants in Chinautla, the Pokomam of that village differs less from Pokonchi than it does from the Pokomam of Palin. With regard to other matters, the reports of the untutored native are not always accurate, but comparisons based on the possibility of understanding the speech of neighboring localities are on the whole quite in conformity with the facts. We give considerable credence, therefore, to the report that Pokonchi and Pokomam are not different languages.

The historical implications of the gradual linguistic diversity observed in Guatemala are rather clear. They definitely suggest that the present distribution of languages and dialects is of long standing. That inference is equally valid whether we assume a long process of mutual influence upon languages which were at one time more divergent than they are now, or whether we assume that the languages diverged from one common source at approximately the same places where they are spoken at present. In this respect, the apparently sharp differentiation of Mam from some of the contiguous languages must be significant, although for the present we can not venture to say what it indicates.

#### GUATEMALA TEXTILE INVESTIGATION—LILA M. O'NEALE

It is unlikely, because of climatic conditions, that any representative group of textiles or other perishable materials dating from pre-Colombian periods in Guatemala will ever be recovered. It is, therefore, chiefly by inferences based on surviving fundamental techniques that the artistry and the very evident technical skill of the old weavers as shown in the

carvings must be interpreted. There are no such elaborate costumes extant today as were worn in the prehistoric periods, but unless new tools and obviously introduced devices be found, it seems reasonable to believe that some of the ancient methods of making fabrics are still in use.

The investigation carried on by Dr. O'Neale during the first half of the year had the following objectives: to visit the highland centers of weaving; to study the methods of producing cloth from native and imported materials; to study the use of simple sticks and more or less crudely shaped tools; to analyze the seemingly complex techniques in terms of skills with which those tools have been adapted to a variety of pattern requirements. Mat-making and basketry were arbitrarily eliminated, as fabrications of materials which do not require spinning.

The methods of gaining data and information were direct. If possible, the market of a center was visited several times. Whenever details of technical interest or of patterning were noted, efforts were made to find women who knew how to weave the specific features shown by the fabric. Special orders involving the duplication of the features were then given, usually with the stipulation that they were to be executed in the presence of the investigator. The general territory covered may briefly be characterized by centers:

1. The Guatemala City—Antigua area: This district represents artistic rather than technical diversity. The typical patterning depends upon some form of brocade, in the main.

2. The Tecpan area: The costumes from several smaller centers show techniques ranging from heavy brocade to sketchy embroidery. In the two areas mentioned there is an increasing amount of work being done by the professional weavers of certain villages. The logical development out of a tendency toward specialization seems to be the purchase of factory-made materials and complete independence of the product of hand looms. Most of the Indian men's costumes have reached the point where the banda or sash is the sole remnant of hand weaving.

3. The Lake Atitlan area: The costumes in this part of the highlands are simple, the techniques are fundamental, and the conventional patterning entails little in the way of individual ingenuity.

4. The Chichicastenango area: Here the complexity of the standard designs woven in silk, wool, or cotton by the women, and the elaborate embroidery in silk on heavy home-spun black wool garments by the men are the main features of the textiles. The men's work, because still done for themselves, remains of higher quality, in general, than the women's weaving which has noticeably deteriorated during the last two years. This is an expectable result of a demand for trade products in primitive communities.

5. The Momostenango area: This is the region celebrated for its work in wools, its dyeing with natural dyes, weaving in fundamental as well as eccentric patterns, and felting. While the spinning and weaving are done almost entirely with appliances derived from Europe, dyeing and felting are still accomplished by simple methods known to be used by primitive craftsmen in other parts of the world.

6. The Quezaltenango-Salcaja-Totonicapan area: From the standpoint of methods and production, this area is unusually rich. There are still a number of small pueblos in which all the materials for the women's huipiles, and even some of the men's garments, are made on back-strap looms. There are, too, in this district, masses of materials made on foot-power hand looms, and on draw looms like those which preceded the Jacquard. In addition to the hand-loom products, there are the increasingly available materials coming steadily from the modern factory at Cantel. Salcaja supplies a large percentage of all the skirts which have patterns in tied-and-dyed yarns. Embroidery is done professionally by women, especially those of San Cristobal Totonicapan.

7. The San Pedro Sacatepequez (Departamento de San Marcos) area: This center is a smaller Quezaltenango in the type and quantity of fabrics which come from its looms. Yet, side by side with yardage output, there may be found the weaving of huipiles by the women on their back-strap looms.

8. The Coban-Salama-Rabinal area: The costumes in this district are simple, but the techniques represent a high degree of skill. This is the only highland region in which gauze weaving is typical. The handling of fine single-ply cotton yarns in two varieties of the gauze weave says not a little for the manual skill of the weavers of the district. Also, besides the thin brocaded fabrics, there are the elaborate heavy brocades of Tactic, and the delicate embroidery of Coban, at this time usually executed on factory-made materials.

9. The Huehuetenango area: This pueblo is the market center for a district rich in various types of hand weaving with both cotton and wool yarns. Unfortunately, unless one is prepared to go on beyond automobile roads, there is little in the way of actual result to be gained from a visit. Some of the most interesting fabrics in Guatemala come from the area bounded on the south by Comitancillo and on the east by Sacapulas. Because of the comparative isolation of the villages within this rectangle, there should be remnants of techniques which have persisted over a long period of time.

The textile fabrics of today in the Guatemala highlands are not technically complex, but they do show distinct local variations. The simple back-strap loom may be held responsible for the several modifications of the plain over-one-under-one weave, many types of weft-face brocades, several standard twills, and the gauzes. There are also warp-face pattern materials, and pile-loop weaves. Of the eight standard weaves known through modern fabrics, only the satin and the double-cloth are missing. The materials used are cotton, rarely hand-spun in these days, wool, silk of different qualities, and a deplorably increasing amount of artificial silk.

#### MAIZE INVESTIGATION—J. H. KEMPTON, WILSON POPENOE

Civilizations, like armies, progress on their stomachs. Without an assured food supply neither can advance. Agricultural practises that release the greatest numbers from the production of food provide the best conditions for the development of the other arts and of the sciences by which the

cultures called civilizations are evaluated. Even under our highly organized and efficient social order, about one-quarter of the labor of the average wage earner is required to obtain the family's food. Viewed from this standpoint the agricultural American Indians are not our inferiors.

The development of the corn plant and the mastery of its culture made the American Indian civilizations possible, if indeed the expanding agricultural art did not make the civilizations. At the time of the Discovery the corn civilizations were highly developed and the archaeological evidence shows that maize was a cultivated cereal at least as early as the beginning of the Christian era.

The origin of this cereal, which is the most valuable crop produced in the United States, is an unsolved mystery. It is known that maize is a purely American plant unknown in the Old World until the voyage of Columbus. The creation of this cereal is an achievement of the American Indian, and an understanding of its origin would contribute to solution of the problem of the antiquity of man and of agriculture in America.

The closest relative of Indian corn is a broad-leaved grass, *Euchlaena*, usually known by its Aztec name, teosinte. There are two species of this grass, one an annual, the other a perennial. Both are found in Mexico, commonly around the margins of cornfields. Until recently *Euchlaena* was unknown in the wild state outside of Mexico, but in 1932 Dorothy and Wilson Popenoe found it in southern Guatemala.

Although the relationship of teosinte to maize is so close that the annual species produces fully fertile hybrids in crosses with maize, botanists are not in agreement as to what position teosinte occupies on the maize family tree. All are agreed, however, that it is associated with the origin of maize.

At the present time the distribution of teosinte demarks the presumptive region in which maize originated, since it is self-evident that all domesticated organisms, whether plants or animals, have been derived from wild ancestors. Accordingly, as part of the project concerning the origin of maize and the maize culture of the Indians, an expedition was put into the field in Guatemala in October 1935, with the object of determining the area occupied by teosinte in southern Guatemala and the connection, if any, between the teosinte of Guatemala and that of Mexico.

The personnel of this expedition consisted of Dr. Wilson Popenoe, of the United Fruit Company, and Mr. J. H. Kempton, of the U. S. Department of Agriculture.

The expedition first visited Jutiapa in the Department of the same name, where the Popenoes had discovered teosinte in 1932, and from there proceeded to El Progreso and to Lake Retana, the latter in the adjoining Department of Jalapa, finding teosinte in abundance in both places. The La Paz drainage basin including Lake Retana and Lake Atescatempa in Guatemala and Lake Guija in El Salvador were visited, but teosinte was not found far south of Lake Retana and appeared not to grow below 3000 feet. Inquiry disclosed that it grows at Moyuta and at Papaturro, both in the Department of Jutiapa, so that in southern Guatemala this plant occurs sporadically within a triangular area having Lake Retana, Moyuta and Papaturro as the points. Within that region this grass is well known under its Aztec

name, teosinte, which may have been assigned during the Aztec occupation of this territory in pre-colonial times.

From El Salvador the expedition retraced its steps to the Department of Huehuetenango in northwestern Guatemala to visit Camoja, from which locality Weatherwax had reported teosinte. This report proved to be unfounded, but as the expedition moved on toward Mexico a vast acreage of teosinte was discovered centering on the town of San Antonio Huixta in the valley of the Grijalva River. There teosinte, known locally by the Jacaltecan name Salic or Salicim, is the dominant plant in the vegetation, completely occupying the steep slopes and tablelands between four and five thousand feet.

Although the plants were just flowering on October 31 it was apparent that in the characteristics of the rachis segments this teosinte closely resembles the Mexican form. Cytological material was collected and a subsequent study of the chromosome morphology by Dr. A. E. Longley places this form in an intermediate position between the teosinte of southern Guatemala and that of Mexico.

The expedition next moved on to Jacaltenango and thence to Nenton. A few scattered plants of teosinte were found at both places, but Nenton proved to be the northernmost locality for teosinte in Guatemala. From Nenton a visit was made to the Finca Chanquejelve where Oliver La Farge had observed what he believed might be a primitive corn or a maize ancestor. What he had taken for a small ear of corn proved to be the spadix of an aroid (*Spathiphyllum friedrichsthali* Schott).

Shortly after leaving the Finca Chanquejelve the expedition entered Mexico where the region in the state of Chiapas between Gracias a Dios and Tuxtla Gutierrez was traversed via Comitán, San Cristobal and Acala, without discovering teosinte anywhere along the route. Since the Huixta River is a tributary of the Grijalva it was expected that teosinte might grow along its course, but though the conditions, except altitude, seemed favorable for its occurrence it was not found.

As a result of the expedition it seems certain that teosinte at the present time is more abundant and less restricted to cultivated areas in Guatemala than in Mexico. In so far, therefore, as this plant may be considered as directly involved in the creation of maize, the most probable region for the origin of maize would appear to be the highlands of western Guatemala.

#### ANTHROPOLOGY AND HUMAN GEOGRAPHY—MORRIS STEGGERDA

The Department of Genetics has continued its greatly appreciated cooperation with the Division of Historical Research by making it possible for Dr. Steggerda to continue field work in Yucatan.

Dr. Steggerda's program for comparative studies on the growth of children of different races has included measurements of some 146 Maya children, 81 of whom have now been measured five or six consecutive years. Forty-six observations have been made on each of these children each year. During the past year Dr. Steggerda has attempted to secure a large number of additional children of each age, in order to establish standards

to which growing children may be compared for individual differences. At present, individual growth curves for 15 of these observations have been plotted for each of the 81 Maya children measured five or six years. Next will follow a comparison with other races. In this connection it may be said that for all ages from six years to adulthood the Maya average about 10 cm. shorter than Navajos. Thus, the characteristic of shortness already exists at the age of six, perhaps even earlier, and persists throughout the growing years. Data for ages below six are being accumulated.

The study of tooth decay among the Maya has now been completed. The Maya have excellent teeth. Evidence for this statement is based upon comparative studies made by Dr. Steggerda on Navajo Indians, Jamaica Negroes and Dutch Whites. For the age group between six and ten years there were 16 times more individuals among Dutch Whites affected by tooth decay than among the Maya, and in the 11- to 15-year class there were eight times more Whites than Maya. Considering the percentage of carious to sound teeth in the two groups, the Whites were 21 times higher than the Maya in the 6- to 10-year class, six times higher in the 11- to 15-year class, and nine times higher in the 16- to 20-age group, in which group all milk dentition had been lost.

One problem which concerns all anthropologists is the age and cause of death in a population. There are records in Yucatan which give date and cause of death, and a stated age for each entry. The recorded ages, however, are nearly all in round numbers. An earnest effort was made this year to determine the degree of error in the stated age in the Yucatan death records. This was done by securing the birth record of as many death entries as possible. Thus in the 35- to 39-year age group the fluctuations from the correct age ranged from minus fourteen to plus nine years in error. Only four out of twenty entries were given accurately. It is hoped that in another year enough figures for all ages will have accrued to indicate the statistical error in the Yucatan death records. If this can be determined we shall be able to state accurately the life span of the Maya.

Dr. Steggerda's agronomic survey has reached the point where it can be said that the average size of 442 farms (milpas) in the Chichen Itza area equals 97 mecates or 9.6 acres. This average was calculated over a 4-year period during which weather conditions caused fluctuations in milpa size, making the average more significant. In the fertile Puuc area 122 milpas near Pencuyut average only 4.5 acres, which is less than half the size of those near Chichen Itza. The data also show that the first-year milpas are approximately 15 to 20 per cent larger than second-year milpas.

Estimates of corn yield in the Chichen Itza area were obtained from 111 farms. The estimated average yield was 0.72 cargas per mecate. First-year milpas yield 0.80 cargas and second-year 0.63 cargas per mecate. Realizing that these figures were based on very rough guesses, Dr. Steggerda enlisted the cooperation of some of the most influential farmers in weighing and measuring all corn produced on a given field. When this was done the figures increased tremendously; for example, on four such farms the yield was found to be in one case  $1\frac{1}{4}$  cargas per mecate, in two cases  $1\frac{1}{2}$  cargas, and in the fourth  $1\frac{2}{3}$  cargas per mecate or, in American terminology,

an average of 25.3 bushels per acre, which compares favorably with the average yield throughout the United States. The results, however, are still inaccurate, since the length of the measuring rope with which the ground is laid out varies from 19 to 23 meters. In another year it is hoped to eliminate this error.

The results of experiments on soil deterioration are accumulating. At present, after four years, there seems to be as much fluctuation in amount of nitrogen, carbon, calcium, phosphorus, etc., in the control plot, which is in uncultivated bush, as there is in the other plots, one of which is in active corn production and the other reverting back to bush. This fact lends evidence to the theory of weed competition recently advanced by Mr. Kempton of the U. S. Department of Agriculture.

With the cooperation of Mr. Ralph Roys, Dr. Steggerda selected from Roys's "Ethno-Botany" thirty plants which were most commonly used as medicine by the Maya in the Eighteenth Century. Roys states in his introduction that many of these usages have altered little since the Sixteenth Century, when Maya medicine was still unaffected by Spanish influence. From the writings of three present-day Yucatecan doctors and verbally from four Indian herbalists from different pueblos, the present usages of the plants in question have been learned. Twelve of the 30, or 40 per cent, all of which have been scientifically identified, have been employed consistently over several hundred years by the Maya for specific ailments. In the other eighteen cases there was confusion in vernacular designations, the same common name being applied to different plants, thus Roys's citations may apply to species other than those under consideration. Five of the thirty plants put to service in colonial times are not used by modern herbalists, and two now consistently employed for specific complaints were formerly used for other diseases. Although it has been stated that there is but little pharmaceutical science involved in the medicinal usages of plants by primitive people, it is nevertheless interesting that confidence in the therapeutic value of 40 per cent of the group should have persisted for nearly four centuries.

### SOUTHWESTERN RESEARCH

Both Mr. E. H. Morris and the Chairman have spent the greater part of the year in preparing publications. Mr. Morris has completed his compendious monograph upon the archaeology of the extremely important La Plata area lying north of the San Juan River in northwestern New Mexico and southwestern Colorado. He then began work on materials gathered in 1931 from Late Basket Maker habitations in the Red Rock Country in northeastern Arizona. During the early summer Mr. Morris made a trip to this region in company with Dr. Emil W. Haury of Gila Pueblo in order to gather further specimens of archaeological wood for dendrochronological studies.

The Chairman finished and saw through the press the second volume of *The Pottery of Pecos*, a work written in collaboration with Miss Anna O. Shepard of the Laboratory of Anthropology. This is the seventh number of the series of publications upon the Pueblo of Pecos. The eighth and last, covering the excavation of the ruin, is now in preparation.

Under the joint auspices of Gila Pueblo, Peabody Museum of Harvard, and the Division, Dr. George Woodbury is making an intensive study of all skeletal material from the earlier cultural groups of western United States: Basket makers, cave- and bluff-dwellers, etc. He is also examining such osseous remains as have been attributed, because of typological peculiarities or from the circumstances of their occurrence, to geologically ancient man in America. Dr. E. A. Hooton of Harvard is in general charge of the work, which is in the second year of a three-year program. Dr. Woodbury has recently completed observation and measurement of all available specimens, and is now engaged in analysis of the large amount of raw data collected.

By courtesy of the Laboratory of Anthropology, the Division has had the invaluable cooperation of Miss Shepard in technological researches upon the pottery collected by Mr. Morris in the La Plata area. Her report is appended.

#### TECHNOLOGICAL STUDY OF LA PLATA POTTERY—ANNA O. SHEPARD

A preliminary technological study of La Plata pottery has been undertaken at the request of Mr. Earl H. Morris. Approximately six months have been devoted to the work, the results of which will be summarized in Mr. Morris' forthcoming monograph, *Contributions to the Archaeology of the La Plata District*. The specific purpose of the study has been to identify the kinds of clay, temper, and pigment used by La Plata potters, and to learn whether or not there was continuity in method of pottery making throughout the region and during the entire span of its occupation.

Descriptions have been based primarily on representative sherds selected by Mr. Morris, and on entire vessels in the University of Colorado Museum. Thin sections of 240 La Plata sherds and of 62 sherds from neighboring regions have been prepared for petrographic analysis. The areal distribution of traits has been partially and tentatively outlined through the microscopic examination of over 3000 sherds from 95 sites. Particular attention has been given to the properties of pigments and to the method of firing, the study of each having required new procedures.

The changes in ceramic practise recorded by the type sherds have been consistently borne out by the surface survey sherds from more widely distributed sites. A brief statement of results will indicate the nature of the evidence. Two principal kinds of paint and two pastes were used by La Plata potters. Basket Maker III pottery was decorated not only with both organic and iron ore pigments, but also with lead glaze (identified spectrographically by Dr. E. G. Zies). This glaze, unlike that occasionally found on later black-on-white pottery, was made from a material essentially different from the ordinary paint, and its occurrence at this stage alters our concept of the general outline of Southwestern ceramic history. During Pueblo I and II only mineral paint was used; but it was finally replaced by organic paint, which first reappears on Pueblo III pottery. The two pastes also ran independent courses. From first to last some types of pottery were tempered with ground igneous rock, one variety of which has been found as drift in the La Plata River. The practise of tempering with



ground potsherds became established in Pueblo II, and by Pueblo III there was a distinct geographic distribution for rock and sherd temper, and some correlation between kind of paint and temper.

Several questions regarding the basic technique of Pueblo pottery making are clearly defined by the La Plata material. Although the characteristics resulting from these techniques are so familiar to workers in the field that they have long ceased to cause comment or wonder, a few attempts to reproduce the pottery bring out extremely interesting problems and give a better understanding and appreciation of the accomplishment of the potter. The gray or grayish-white color of the clay and the black pigments, either organic or reduced iron oxide, are produced by firing in a reducing atmosphere. How was such an atmosphere maintained? Experiments, in all of which Mr. H. Warren Shepard has given essential aid, have included the construction of an underground kiln copied after pits, showing the effects of high temperatures, which have been found in Mr. Morris's excavations. The practicability of these pits for pottery firing and the temperatures and atmospheres which can be obtained have for the first time been tested. The Chemistry Department of the University of New Mexico has cooperated by furnishing apparatus for gas analysis. The method of producing a permanent black paint from an iron ore involves problems directly related to those of firing and no less complex. Dr. Zies is materially advancing this study through the application of spectrographic analysis, and the first examination of polished sections of paint has been made possible through the courtesy of Dr. J. W. Greig in loaning necessary instruments. These methods are being supplemented by firing experiments.

It has been found that La Plata potters were conservative in ceramic practice, they used relatively few materials compared with other Pueblo groups, and they occupied a region of comparative geologic uniformity, which augments the standardization of their pottery. Consequently, evidences of local interchange in pottery are not conspicuous. But the technological data appear none the less interesting, for periods of innovation and diversification alternate with periods of conservatism. In every instance of change in established custom, we may ask whether the cause was foreign influence or indigenous development, and to what extent expediency and availability of materials shaped progress. Pottery making, moreover, had become a highly specialized craft and a record of the course of its evolution occupies a natural place in the history of the people. A detailed comparison of the technological and the stylistic features of pottery and a correlation of ceramic data with other aspects of material culture, as well as more complete technological study will be necessary to answer all of the questions which have been raised.

#### STUDY OF MAYA COLONIAL DOCUMENTS—R. L. ROYS

During the period under review Mr. Roys has been engaged in translating and editing for publication the *Titulos de Ebtun*, which are the archives of an old Indian town in eastern Yucatan. These papers have proved to be of value not only for the history of the immediate area, but also in their relation to other activities of the Division, for although Ebtun is situated near

Valladolid, its lands were scattered westward over a considerable area; and the Titulos contain information regarding a region extending almost to Chichen Itza in the north and along the ancient roadway to the ruins of Yaxuna in the south. This includes, wholly or in part, the field of Dr. Redfield's and Alfonso Villa's ethnological study at Chan Kom,<sup>1</sup> Dr. Shattuck's medical survey,<sup>2</sup> Dr. Steggerda's anthropometric work<sup>3</sup> and Alfonso Villa's survey of the roadway,<sup>4</sup> not to mention the archæological work at Chichen Itza, practically on the edge of this area.

Consequently the Titulos de Ebtun furnish a valuable historical link between the pre-Conquest inhabitants and their descendants, who still constitute the bulk of the population of the region. The recent studies of the physical environment, mentality and daily life of the modern Maya have added considerably to our understanding of the significance of the archæological remains; and if the present is to continue to illuminate the more remote past, it becomes increasingly important to trace the connection between them.

Photographs of the documents have kindly been loaned by the Peabody Museum of Harvard University, and Tulane University has permitted use of materials gathered during a preliminary study made under its auspices.

The original documents have also been consulted by Mr. Roys at Ebtun; and it has been possible to map nearly all the many localities cited in them from topographical data previously collected by Dr. Redfield, Alfonso Villa and the writer, supplemented by subsequent information from J. I. Rubio Mañé and Lawrence Roys.

The earliest Ebtun document, dated 1561, has been found in another collection, and the archives now at Ebtun begin in 1600 with a series of boundary treaties. These were concluded between Ebtun and four other associated southern Cupul towns, on one side, and their western neighbors of the former independent state of Sotuta on the other. Certain Sotuta documents will also be presented containing the Spanish translation of a boundary survey made by Nachi Cocom in 1545. As this date is believed to precede the writing of Maya in European script, the original record was probably one of the *pinturas*, which we find mentioned, or a hieroglyphic map.

Among the 1600 documents, some of the most interesting are those which tell in considerable detail of the scattered villages and hamlets whose rural population was concentrated in the five towns under Tomas Lopez about the middle of the Sixteenth Century. Here occur the pagan names of the last inhabitants of these places and those of their Christian descendants in the towns. Ancient ruins are still to be found on a large number of these sites, or "old towns" as they are called in the documents.

There are indications that land ownership in such rural settlements may have been largely a family affair. This is of interest in view of Gaspar Antonio's statement that lands were held in common. Family ownership of

<sup>1</sup> Carnegie Inst. Wash. Pub. No. 448.

<sup>2</sup> Carnegie Inst. Wash. Pub. No. 431.

<sup>3</sup> Year Books No. 32, 206; and No. 34, 131.

<sup>4</sup> Carnegie Inst. Wash. Pub. No. 436.

land used for farming certainly goes back to 1561 in some cases, and how the presumed change from communal ownership came about is not yet entirely clear.

Sometimes, either by direct transfer or through a temporary Spanish owner as intermediary, land passed from one town to another. This usually caused trouble. In the case of the Tontzimin tract near Chan Kom, its sale by an Ebtun man to a resident of Cuncunul in 1638 resulted in a series of bitter disputes and law-suits which ended only in 1820.

The many land-transfers and surveys constitute in themselves a documentary history of the town of Ebtun. We find individual and communal ownership of lands existing side by side. Although the higher municipal offices were usually held by a limited number of prosperous land-owning families, it was always the policy of the town to increase the communal holdings, apparently for the benefit of the poorer inhabitants.

Frequently these documents tell how and from whom the vendor acquired the property, whether by purchase, gift, or inheritance. Sometimes the reason for the sale was a famine, when people had gone to the forest to live on wild fruits and roots. More often it was due to poverty arising from sickness or old age, especially when the owner had neither sons nor sons-in-law to cultivate the land. Occasionally the vendor invokes such penalties as fine and flogging, if he should ever afterward question the validity of the sale. In a few cases there is even information as to how the buyer acquired the purchase money.

Among these papers are a number of wills listing the possessions of the more well-to-do members of the community. Bequests were mostly of beehives, tools, household paraphernalia, forest lands, fruit-trees, town lots and the home of the testator. Lands were often bequeathed as joint property of all the children, but we sometimes later find them subdivided or the various interests bought up by one or two of the heirs. Few horses and practically no cattle were willed. Cattle raising, with the resulting damage to unfenced crops, was very unpopular, although it was extensively practised by Spanish land-owners.

Other documents are Maya translations of proclamations by the governor, a few complaints of ill treatment by Spaniards, records of purchases of municipal supplies and commitments to jail, usually for wife-beating or disrespect to the local authorities.

Among the people of the region today, Ebtun is noted as the mother of colonies; and it was due to her land policy that a number of villages, Chan Kom among them, have since sprung up on what were formerly the communal lands of this town.

## SECTION OF UNITED STATES HISTORY

The work of the members of the Section is set forth below. Correspondence and editorial work, together with preparation and publication of the annual list of doctoral dissertations in history, have been conducted by Margaret W. Harrison, editor of the Division.

During the past year the eighth and final volume of Dr. Edmund C. Burnett's *Letters of Members of the Continental Congress* has been going through the press and it is expected that the book will appear in August 1936. This volume, covering the period January 1, 1785, to July 25, 1789, contains a supplement of thirty letters from the years 1783-84.

Volume IV of Dr. Leo F. Stock's *Proceedings and Debates of the British Parliaments respecting North America*, now ready for the printer, was described in last year's report. Probably half of the materials for the fifth volume has been assembled. While much of the coming year will be devoted to the processes of seeing volume IV through the press, it is expected that substantial progress will be made in the remaining time in the work of annotating these materials for volume V.

In November 1934, Dr. James J. Hayden, of the District of Columbia and Maryland bars and a member of the faculty of the Catholic University Law School, undertook completion of the final volumes of *Judicial Cases concerning American Slavery and the Negro*, which were unfinished at the time of Mrs. Helen Tunnick Catterall's death. The fourth volume covering cases from New England, the Middle States, and the District of Columbia, will be published in July 1936. Dr. Hayden has completed the work on the fifth and last volume, which will include cases from the states north of the Ohio and west of the Mississippi Rivers, and it is hoped that this series will be finished early in 1937. Dr. J. Franklin Jameson has given personal supervision to the preparation of these two final volumes.

Dr. Waldo G. Leland resumed work on his *Guide to Materials for American History in the Libraries and Archives of Paris*, the first volume of which was published in 1932. It has been arranged that Dr. John J. Meng, instructor in politics at the Catholic University of America, will examine in Paris during the summer of 1936 volumes of the Foreign Office archives for the period between 1848 and 1870.

After the publication of his *Guide to Materials for American History in Russian Archives* in 1917, Dr. Frank A. Golder, late professor of history and a director of the Hoover War Library at Stanford University, made supplementary notes in Petrograd relative to the correspondence between the Russian diplomatic agents in America and the Russian Foreign Office. This supplement, continuing the correspondence from 1854 to 1870, is now being prepared for publication and should appear before the end of 1936.

Mr. David M. Matteson, indexer of the publications emanating from this Section, has prepared the indexes to the fourth volume of *Judicial Cases concerning American Slavery and the Negro* and to the eighth volume of *Letters of Members of the Continental Congress*. He has continued to make progress in the general index to *Writings on American History*. His work on the index to the *Calendar of Manuscripts in Paris for the History of the*

*Mississippi Valley* has been indefinitely suspended. Mr. Matteson is historian of the United States Constitutional Sesquicentennial Commission.

Dr. Charles O. Paullin has completed the abstracting of the first seventeen volumes of the *Dictionary of American Biography* and will complete the series soon after the publication of the twentieth and last volume in the latter half of 1936. He has begun the work of studying the abstracted information, calculating the averages, preparing tables and diagrams, and writing the text. It is now possible to orient the investigation, to note its methodology, and to forecast some results. One may classify the sciences, accurately enough for present purposes, as mathematical, physical, biological, and social. Since man is a biological as well as a social creature, the two last-named classes are not mutually exclusive, and the present investigation, which primarily falls into the last class, is also a study in biology.

For several centuries interest in the social sciences has been growing, and as a result the number of workers in them in recent years has steadily increased. These may now be divided into three groups. In the first group are the archivists, editors, librarians, and educators, who preserve, classify, and disseminate social information. In the second group are the historians, biographers, economists, and political and other scientists, who use the materials preserved by the first group in the production of a more finished product. The members of the third group take the materials of the first and second groups and attempt to discover fundamental patterns, ratios, sequences, and laws. They search for the general truth that lies back of innumerable details and try to reduce complexity to a simple formula. They are interested in the particular only as it illuminates the general. Their product is impersonal; they are explainers and labor savers. Owing possibly to the niggardliness of nature or the ineptitude of man, very few scholars qualify for service in the topmost rank of this group, alongside such scientists as Adam Smith, Herbert Spencer, and Sir Francis Galton.

The slow progress of the social sciences compared with the rapid advance of some of the other sciences has often been remarked and lamented, but never more frequently than during the last seven years. Critics have sometimes given a sharp edge to their criticism. They compare the social scientists to men who are content to dig out ore, clean it, and store it away, indifferent to the smelting, refining, and manufacturing processes. They, however, pass lightly over the difficulties which beset the social investigator. These may briefly be summarized: His materials are in a state of evolution; they are dynamic, while those of the mathematician and physical scientist are static. He can not experiment with his materials; there is no laboratory in which he can reproduce them and study them at his leisure. In the social sciences relationships are complicated. Each effect has many causes; and each cause, many effects. If a cause or an effect is isolated, an abstraction results that has little relation to reality. Moreover, the social scientist is unable to separate himself completely from his investigation—to view it objectively. He is more or less influenced by his instincts, emotions, traditions, prejudices, and interests. For this reason the conservative social scientist disagrees with the radical; the Protestant, with the Catholic; and the English, with the German or other national brand. All scholars run the

risk of being trapped by the prevailing modes of contemporary thought, particularly by fashions in their specialties.

Recognizing these difficulties, an investigator of average ability may take such precautions as are open to him. He may wisely leave to other minds the discovery of fundamental laws and confine his efforts to such secondary matters as ratios and patterns. He will adopt the methodology of the social statistician, which is the application of mathematics to social information. Invoking the aid of the "queen of the sciences," as mathematics is sometimes called, he will acquire increased respect for this able and willing coadjutor, whose great part in revolutionizing modern life is generally not fully recognized. He may well start with the assumption that most things that exist, exist in quantity. If they exist in quantity, they can be measured; and if they can be measured, it is the duty of some one to measure them. Lord Kelvin's words are pertinent: "When you can measure what you are speaking about, and can express it in numbers, you know something about it, and when you can not measure it, when you can not express it in numbers, your knowledge is of a meager and unsatisfactory kind."

There is another methodology which draws on intuition and imagination in explaining, generalizing, and synthesizing. While this is of the greatest importance, the average investigator may well use it sparingly. The results obtained from the two methods differ in authenticity. The mathematical results deserve the greater credence. Intuition and imagination vary with the investigator; their products are to be regarded as provisional and as subject at all times to revision. The art of classification is fundamental in such investigations as the present. Here and in "insufficient data" one must be on his guard for pitfalls.

Doubtless many persons have noted that the interval between the death of a wife and the remarriage of the widower is of varying length. Apparently no one hitherto has thought of measuring it. Deprived of habitual satisfactions, his domestic arrangements disorganized, the widower soon puts a period to his mourning and seeks in remarriage a cure for his ills. Good form is thought to dictate a minimum of some eighteen months before remarriage, but it is often violated. The following figures are for the first thousand measurable cases in the *Dictionary*—1 year, 218; 2 years, 254; 3 years, 156; 4 years, 96; 5 years, 52; 6 years and over, 224. "1 year" means under  $1\frac{1}{2}$  years; "2 years," from  $1\frac{1}{2}$  to  $2\frac{1}{2}$  years; "3 years," from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  years, etc. The most frequent interval is 2 years; and the next most frequent, 1 year. The percentages are found by pointing off one decimal place. For the first two years the percentage is 47; for the first three, 63; and for the first five, 78. The shortest interval is that for Thomas Fortune Ryan (1851-1928), financier, 12 days; the longest that for Denton J. Snider (1841-1925), author, 42 years. Since the population increases or decreases inversely as the length of the interval, the marital speed of widowers is, from a social point of view, a matter of importance.

Looking casually at a collection of social facts, such as that found in the *Dictionary*, one is impressed by diversities and differences. A closer examination, however, reveals many uniformities and similarities. The aim of all science is to discover unity in diversity. Social facts tend to arrange

themselves in patterns. The ground plan of every human life is much the same—birth, infancy, education, occupation, domestic arrangements, achievements, disease, and death. Shakespeare gave poetic expression to this in man's "seven ages," beginning with the "infant, mewling and puking," and ending with "sans everything." One discovers many patterns in the *Dictionary*—patterns in origins, birthplaces, residences, education, occupations, marriages, diseases, recreations, mental and physical traits, etc. Such patterns may be illustrated by an occupational one: In respect to the number of occupations in which a *Dictionary* character achieves eminence there are two well-defined types, the unit-occupation type and the multiple-occupation type. Clearly of the former type are Augustus St. Gaudens, sculptor, and George Dewey, naval officer. In the one case outside of sculpture, and in the other outside of the navy, there was no achievement worth mentioning. Franklin, Jefferson, and Theodore Roosevelt are of the second type. Franklin was eminent as printer, author, philanthropist, inventor, statesman, diplomat, and scientist; Jefferson, as statesman, diplomat, author, scientist, architect, and reformer; and Roosevelt, as statesman, army officer, historian, journalist, naturalist, and explorer. It is not easy to say which type is the higher.

#### HISTORY OF YUCATAN—F. V. SCHOLES

The documentary research for the monograph on the *cacicazgo* of Acalan-Tixchel has been completed, and it is hoped that the manuscript will be finished by the end of 1936. This volume will contain: (1) The history of the *cacicazgo* over a period of ninety years beginning with the expedition of Cortez to Honduras and ending with the removal of the missions in Ichbalche, Tzuctoc, Ichmachich, Chunhas, etc., to the region of Sahcabchen in 1615; (2) facsimile reproduction of the Chontal text describing the history and services of the *caciques* of Acalan-Tixchel; (3) an annotated Spanish translation of this text; and (4) a brief statement concerning the aboriginal history, ethnography, and linguistics of the area comprising the *cacicazgo*. Miss Adams, Mr. Roys, and Mr. Scholes are collaborating on this work.

Although this monograph will throw a flood of light on the Acalan-Tixchel area, the lack of adequate geographical and archæological information concerning the region makes it difficult to form definite conclusions on many essential points. Perhaps no part of Spanish North America has been less explored in recent times than this area, which lies east of the Usumacintla and south of Laguna de Terminos. An expedition of reconnaissance for archæological and geographical purposes is greatly needed.<sup>1</sup>

Considerable progress has been made on the documents dealing with the life of Fray Diego de Landa and the beginnings of the Inquisition in Yucatan. The materials from the Archivo General de Indias in Seville, especially those which relate to Landa's investigation of Indian idolatry in 1562, are being thoroughly studied by Miss Adams and Mr. Scholes, and Sr. Rubio Mañé has started work on the Inquisition papers in the Archivo General y Público de la Nación in Mexico City. By the end of December 1936, the documentary work for a volume on the history of the Inquisition in Yucatan

<sup>1</sup> See p. 122.

prior to 1571, when a formal tribunal of the Holy Office was established in Mexico, should be completed.

This monograph and the study of the materials dealing with Landa's career in Yucatan during the 1570's will pave the way for a needed biographical sketch of the bishop. Such a study will be prepared by Mr. Scholes as part of a volume containing an annotated translation of Landa's *Relación de las cosas de Yucatán* to be published by Professor A. M. Tozzer under the auspices of the Peabody Museum.

Materials are accumulating for the history of the encomienda in Yucatan; the first section covering the beginnings of this institution prior to 1550 is rapidly taking form.

Sr. Rubio Mañé has continued his work in the local archives of Yucatan. In October 1935, Mr. Scholes spent a week with him in Merida in conference concerning phases of his investigations. The survey of the parish records in Merida and Campeche has been completed, and considerable time has been spent in searching through the records in other towns in connection with investigations for Mr. Roys and Dr. Morley. At the request of Mr. Scholes a test study was made of the first volume of the marriage records of the Negro parish in Merida, covering the years 1568 to 1610, in order to obtain information concerning the intermarriage of Indians and Negroes. Sr. Rubio Mañé summarized his findings as follows: (I) Marriages—Negroes with Negroes, 19; Negroes with Mulattoes, 16; Negroes with Indians, 42; Mulattoes with Indians, 27; Mulattoes with Mulattoes, 11. (II) Number of Individuals Mentioned—Slaves: Negroes, 105; Mulattoes, 29—134. Free: Negroes, 8; Mulattoes, 19—27. (III) Number of slaves mentioned, 65; average number of slaves per owner, 2+.

These investigations in the records of the Negro parish will be continued when Sr. Rubio Mañé returns to Yucatan at the end of 1936. It is obvious that they will not provide a complete picture concerning the Negro and Mulatto population of the province, but they should provide valuable data concerning the amount and rate of mixture of the Negro and Indian races.

During the past year Dr. Chamberlain's work on the Spanish archive materials for the life and times of Montejo was practically completed. In June (1936) he left for Mexico and Central America, where he will explore the local collections for documents on the history of the Maya area prior to 1550. In view of the fact that the career of Montejo in America extended to 1550 and was so intimately related to the whole Maya region, it is hoped that Dr. Chamberlain may be able to expand his work on the Adelantado into a general history of the conquest of the region from Tabasco to the Rio de Ulua—roughly the entire Maya culture area. It is also expected that as a result of his investigations in Guatemala the Institution will have definite information concerning the general content and volume of the local archives, on the basis of which a decision may be reached with regard to further historical research in the Guatemala area.

Dr. Hanke has carried forward his research on theoretical phases of Indian legislation and policy in the Sixteenth Century.



## SECTION OF THE HISTORY OF SCIENCE AND ALLIED INVESTIGATIONS

### HISTORY OF SCIENCE—GEORGE SARTON<sup>1</sup>

*Introduction to the History of Science*—The preparation of volume III on science and learning in the Fourteenth Century is proceeding slowly. The amount of material to be collected, analyzed, and combined is far greater than had been anticipated. However, the slowness is caused less by the size and complexity of the work, than by the increasing number of interruptions, due to the growing interest of all kinds of people in the history of science. The Jewish part of volume III is the only principal section thus far completed; that is, all the individual notes are practically finished, but according to Dr. Sarton's method synthesis must be postponed until all the notes relative to every aspect of the subject are ready; the analytical stage of the work must be perfected in every possible direction before the synthesis can be begun.

Dr. Welborn has continued revision and amplification of the Latin notes.

Dr. Alexander Pogo devoted the period under review to study of astronomical problems involved in the correlation of Maya and Christian chronologies. His report follows:

*Maya Astronomy*—It is occasionally difficult to decide whether a lunar eclipse should be considered as umbral or as penumbral. Thus, Oppolzer's *Canon der Finsternisse* lists a small partial eclipse occurring 1890 June 3; the *American Ephemeris and Nautical Almanac* predicted a lunar appulse for that date, adding, however, the following remark: "The nearness of the approach and the uncertainty as to the effect of the earth's atmosphere render it doubtful whether the moon will enter the shadow of the earth or not." The small partial lunar eclipse of 348 October 23.96 could be quoted, on the other hand, as an example of an eclipse not listed in the *Canon*; Oppolzer's computations indicated that the eclipse was penumbral, and it was, therefore, not included in the *Canon*; a more elaborate computation, made with the aid of Neugebauer's tables, shows that the moon unquestionably entered the umbra, and that the partial phase ended at sunset, as far as eastern Yucatan is concerned, or before sunset for the rest of the Maya territory.

The ecliptic nature of the pentamenos and hexamenos count preserved in Glyph C of the Supplementary Series is obvious; the Maya must have known that it is easier to determine the beginnings of these periods not directly, by waiting for the infrequent eclipses of the new moon visible in their territory, but indirectly, by subtracting 15 days from the dates of the frequently observed eclipsed full moon. The compilers of the table of ecliptic syzygies preserved in the Dresden Codex knew that five or six lunations after an observed lunar eclipse, another lunar eclipse was likely to be visible in the Maya territory. Since the darkening of the limb of the moon, when its approach to the umbra is sufficiently close, differs but little from the darkening of the limb during a small partial eclipse, and since the Maya priests were unable to compute the magnitude of an eclipse, or to distinguish, on theo-

<sup>1</sup> Eighteenth annual report for the period extending from July 1, 1935, to June 30, 1936 (Previous reports appeared in Year Books of the Carnegie Institution, Nos. 18 to 34, 1919 to 1936; the 12th and following also appeared in *Isis*, the latest in vol. 24, 422-428, 1936).

retical grounds, between umbral and penumbral eclipses of the moon, it is reasonable to assume that their records of observed lunar eclipses included both small partial eclipses and close appulses. It must be kept in mind that a celestial phenomenon may be too inconspicuous to attract the attention of an indifferent layman glancing at the sky, while it may be sufficiently noticeable to be recorded as observed by an astronomer who was expecting its occurrence.

No study of the lunar calendar of the Maya and of their table of ecliptic syzygies can, therefore, be complete, unless both umbral and penumbral eclipses are taken into consideration. For this reason, a special canon of penumbral lunar eclipses which might have been visible in the Maya territory was computed with the aid of Neugebauer's tables; it covers the two millennia preceding the arrival of the Spaniards. By combining the data of this special canon with Oppolzer's data, the number of Mec groups at "picture" intervals (see the previous report) was increased from 17 to 27; the ten additional groups include from one to four appulses each. The problem of deriving a correlation from these groups, by eliminating spurious solutions, became more complex; on the other hand, the addition of the "picture" groups containing appulses simplified the study of the periodicity of these groups, thus throwing additional light into the dark past whence the Mec emerged. Like the Julian and the Gregorian calendar years with seven eclipses, mentioned in the bibliography appended to this report, Mec groups at "picture" intervals form patterns showing a tendency to congregate in certain centuries and to avoid others. This gives, incidentally, a terminus ante quem for the original Maya ecliptic table, a copy of which was included in the collection of astronomical tables known as the Dresden

Lunar saros series	1st group at "picture" intervals	Lunar saros series	2d group at "picture" intervals	"Picture" numbers	Intervals in days
L141	521 Dec 29.5	L100	554 Sep 27.1	X	502
L158	523 May 15.4	L117	556 Feb 11.4	I	1743
L217	528 Feb 21.3	L176	560 Nov 19.0	II	1033
L 29	530 Dec 20.4	L211	563 Sep 18.0	III	1211
L 70	534 Apr 14.4	L 29	567 Jan 11.2	IV	1742
L129	539 Jan 20.3	L 88	571 Oct 18.9	V	1034
L164	541 Nov 19.5	L123	574 Aug 18.3	VI	1211
L205	545 Mar 14.5	L164	577 Dec 11.2	VII	1565
L 35	549 Jne 25.9	L217	582 Mar 25.2	VIII	1210
L 76	552 Oct 18.5	L 35	585 Jul 17.5	IX	709
L100	554 Sep 27.1	L 59	587 Jne 25.9	X	
					11960

Codex: no group of ten lunar eclipses at "picture" intervals could have been observed in the Maya territory after the middle of the Tenth Century of the Christian era. The most promising centuries, from the point of view of a correlation based on the pages 51 to 58 of the Dresden Codex, are the Fifth and Sixth (10 groups), and the second half of the Eighth and the first half of the Ninth Centuries (4 groups).

The table on page 153 illustrates the cyclical nature of the Mee groups at "picture" intervals: the last eclipse of the first group is the first eclipse of the second group.

*Other Investigations*—Dr. Sarton conducted various studies upon pre-Hellenic science in Crete, Egypt and India. He also made a preliminary survey of the methods which may later facilitate the historical study of Twentieth Century science. The problem to be solved may thus be stated: "If the growth of science continues at the present rate, will it remain possible for any historian, however deep his scientific preparation, to understand and record further progress? And will the historian of, say, the Twenty-first Century be able to write the scientific history of our times? How will he manage to do it? Can we not take steps from now on to facilitate his task or simply to make it possible?" Dr. Sarton conducted some correspondence on the subject with the president and other members of the Institution. He continued his study of Arabic and Arabic science, thus laying a solid foundation for his survey of Arabic science and learning in the Fourteenth Century to be completed next year for volume III of the Introduction.

Dr. Welborn completed a study of deontological traditions in the medical literature of the Fourteenth Century.

*Editing of Isis and Osiris*—During the year 1935-6, four numbers of Isis were published (66 to 69) forming the whole of volume 24, and halves of volume 23 and 25, respectively, a total of 1247 pages, 6 plates, 32 figures and facsimiles. These four numbers contain 34 memoirs, 49 shorter items, 79 reviews and 2675 bibliographic notes.

It had long been felt that the publication of articles of more than 20 pages was jeopardizing the main purpose of Isis, which is to promote the history and philosophy of science as a new discipline, to illustrate on the one hand its wholeness and its complex interrelations and on the other hand as many special aspects of it as possible. It is clear that this can not be properly done if too much space is devoted to any single topic, however interesting. Therefore it has been necessary to establish a new serial, named Osiris (a name illustrating its intimate connection with Isis) wherein longer memoirs will appear as well as collections of articles relative to single subjects. The first volume of Osiris was published in January 1936 to celebrate the jubilee of Professor David Eugene Smith, historian of mathematics, founder of the History of Science Society, and one of the pioneers of the history of science movement in America. It is a volume of 778 pages (same size and style as Isis), with 22 plates, 35 facsimiles and 24 figures, containing 38 studies, most of them relative to the history of mathematics. It may be confidently expected that the publication of Osiris will improve the variety and interest of Isis.

Isis and Osiris together contained 2025 pages, with 28 plates and 91 figures and facsimiles, containing 72 memoirs, 49 shorter items, 79 reviews and 2675 bibliographic notes.

*Center of Research in the History of Science and Learning*—The remarks upon this subject made in last year's report would apply equally well to the present period, but it is unnecessary to repeat them. However, it is worthwhile to emphasize that the continual increase of books and documents, as well as the continual increase in their use by more and more people create difficulties which are becoming perilous. The question arises: Will the activities of this center of research be allowed a normal growth or will they be smothered and stopped? It should be noted that the present state of affairs is not by any means a climax, but only a modest beginning.

#### RESEARCH IN PALÆOGRAPHY—E. A. LOWE<sup>1</sup>

Field work was resumed during the early summer of 1935 in the libraries of Belgium, with visits to Brussels and Ghent, whose *Codices Latini Antiquiores* items were photographed and described. The end of the summer and most of the autumn was spent at Oxford seeing the second volumes of *Codices Latini Antiquiores* through the final stages of press and writing the accompanying preface. Faithful to their promise, the Clarendon Press managed to publish the volume before the year was out. Dr. Lowe wishes to record in this report his appreciation of the extraordinary helpfulness and cooperation received from the officers and staff of the Clarendon Press. No editor could be more fortunate in his printer and publisher.

Field work was carried on by assistants in Germany and France and, since March, also in Italy. The Italian manuscripts will occupy the next two volumes, and the task of revising the descriptions and of getting the photographs will be taken in hand the beginning of July.

A journey of reconnaissance in Spain was made in the Christmas holiday, and the libraries of Barcelona, Toledo, Cordova, Granada, and Seville were visited in the hope of discovering new items. On the way through France the oldest manuscripts of Toulouse and Bordeaux were examined and described; and while in Paris further progress was made in the summary inspection of the first 8000 manuscripts of the *fonds latin* of the Bibliothèque Nationale.

#### HISTORY OF GREEK THOUGHT—W. A. HEIDEL

During the year Dr. Heidel revised his study of *The Frame of the Ancient Greek Maps*, in which he tried to make clear the ground-plan on which the earliest Greek geographers constructed their general maps before the earth was recognized to be spheroidal in form. The disc-earth was conceived as the extension of the horizon, on which there were certain important points, marked by the rising and setting of the sun at the solstices and the equinox. By connecting the eastern and the western points of the respective seasons one drew three parallels, the outer ones being assumed to be at or near the limits of inhabitation, while the central line was accepted as the equator of the *oikumene*. A detailed study of the available evidence shows approxi-

<sup>1</sup> For previous reports see Year Books Nos. 9 to 34.

mately where these lines would fall on the true map. Dr. Heidel investigates also the principal improvements in the map dating from the period prior to the discovery of the sphericity of the earth. In the second part of the study he offers a critical review of the question when and by whom it was first suggested that the earth is really a sphere and then discusses the claims advanced for the several eminent geographers. Eratosthenes is shown to have been the earliest to attempt a map based on the conception of the sphericity of the earth; but the conception itself was older, being traceable to the close of the Fifth Century B.C. The study has been accepted for publication in the Research Series of The American Geographical Society of New York, and will doubtless be issued before the end of the year.

Meanwhile, Dr. Heidel has carried on studies of the general development of early Greek scientific and philosophical thought. For years he has laid considerable stress on the early history of medicine and biology. He has pursued the large group of ideas which the early Ionians associated with Egypt. This led to a careful consideration of the contributions made to historiography, ethnology, geography, and physiography, and their relation to the general stock of ideas that served to interpret experience. He is now engaged in critically reviewing the development of Greek mathematics and astronomy, the last of the major fields in which the Greeks made important contributions to thought. There is still much that remains obscure, but he is convinced that scholars have given undue credit to Pythagoras and Pythagoreans in these fields. No doubt the credit due to them is very great, but it is a palpable mistake to hold that we owe the entire early development of the mathematical sciences to Pythagoreans and their influence. Considerable parts of Dr. Heidel's account have been sketched and written out, but will of course be entirely recast before the whole can be published.

# MOUNT WILSON OBSERVATORY <sup>1</sup>

GEORGE E. HALE, HONORARY DIRECTOR

WALTER S. ADAMS, DIRECTOR

FREDERICK H. SEARES, ASSISTANT DIRECTOR

The appearance of a bright nova in the constellation of Lacerta on June 18 was probably the most remarkable astronomical occurrence of the year. The outburst within a period of 18 months of two such stars, both visible to the naked eye, Nova Herculis 1934 and Nova Lacertæ 1936, is a phenomenon perhaps unique in the history of astronomy. Both stars have been studied extensively at observatories all over the world and the final analysis of the observations should contribute notably to the interpretation of this extraordinary class of objects. The most recent nova is of exceptional interest for several reasons: the rapidity with which the changes in light and spectrum have taken place; the magnitude of the velocities and accelerations of the expanding gases; the definite identification of the nova with a star of the fifteenth magnitude observed in past years; and the presence of strong lines due to calcium and sodium gas scattered throughout interstellar space. Velocities of approach amounting to as much as 3400 km/sec have been observed in the expanding envelope of Nova Lacertæ, the highest velocity ever measured in novæ belonging to our galaxy, and accelerations of 200 or 300 km/sec within 24 hours were found during the first few days after the star's outburst. Observations of the intensities of the interstellar calcium and sodium lines indicate a distance of 800 parsecs (2600 light-years). At its greatest brightness the star had a luminosity about 150,000 times that of our sun.

Nova Herculis has remained relatively stable throughout the year, both as regards brightness and spectrum, but the star has been kept under close observation for radical changes which may be expected to occur in its nebular features. Most of the absorption lines and emission bands have been identified, and the remarkable changes in the widths and character of the bands have been traced and recorded. The fact that forbidden states of the atoms of gas directly between the observer and the star can not give rise to absorption lines may well explain the relative behavior of the permitted and forbidden lines in the spectrum; and the hypothesis that the expanding atmosphere of a nova arises from an explosive impulse which drives off highly condensed material from the star, out of which gaseous atoms later evaporate, would account for many of the complex changes observed.

The discovery at Mount Wilson a few months ago of a supernova in one of the extragalactic nebulae of the Virgo cluster adds an important member to the brief list of these remarkable stars. Found as the result of a long systematic search, it provides one of the most reliable determinations of the luminosity of the brightest objects of which we have any knowledge. At maximum light it was at least 100 times as luminous as Nova Lacertæ and 20 million times as bright as our sun. Observations of its spectrum showed exceedingly wide emission bands, in agreement with the conclusion

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derived from galactic novæ that the width of these bands is at least roughly proportional to the luminosity of such stars.

The extensive preliminary survey of the extragalactic nebulæ for the purpose of forming an estimate of their numbers and distribution and of defining the problems relating to them which may be undertaken to the best advantage with large telescopes has now been completed. It has led to many results of interest, among which the determination of the relative numbers of nebulæ of various luminosities, the evidence that the total luminosities of regular nebulæ of all types are closely comparable and the development and improvement of methods of deriving distances are especially notable. Detailed studies of individual nebulæ have led to important advances, both on the spectroscopic and the photometric sides. Evidence has been gathered which indicates that the unresolved elliptical nebulæ are probably clusters of stars with a range in spectral type not exceeding one or two spectral classes. A definite scale of magnitudes and colors for nebulæ has been established through measures with the photoelectric photometer, and comparisons with observed spectral types show the existence of a color excess for all nebulæ except the late-type spirals. A beginning has been made upon the difficult problem of measuring the rotation of extragalactic nebulæ spectroscopically, an investigation for which a special instrument is now under construction.

Measurements of the red shift in extragalactic nebulæ have made considerable progress during the year and add to the fundamental importance of the interpretation of the shift as a factor in cosmogony. A provisional analysis of the observed results by Hubble and Dr. Tolman of the California Institute of Technology indicates that the red shifts may or may not be ascribed to radial velocity, but that if due to velocity a positive spatial curvature must be introduced with a radius within the observing range of the 100-inch telescope. An observation bearing on the problem of the red shifts has been made with a grating spectrograph upon one of the brighter nebulæ. The same shift is found as with a prismatic instrument, a result which disproves the suggestion that the frequency of the vibrating light-source may vary while the wave-length remains constant. The constancy of the velocity of light in its passage from the nebulæ had already been established within narrow limits by measures of aberration on a cluster of distant nebulæ.

The globular star clusters are among the most remote objects in our galaxy and serve to define the dimensions and form of our stellar system. Measures of the colors of these clusters with the photoelectric photometer by Stebbins and Whitford indicate that, when allowance is made for the effect of absorption by interstellar matter, the overall diameter of the galaxy is reduced by about one half, or to 30,000 parsecs (100,000 light-years), which is of the same order as that of the Andromeda nebula. This result removes most of the discrepancy hitherto supposed to exist between the size of our galaxy and that of other systems. The distances of several of the fainter clusters have been determined by the aid of variable stars occurring in them and the integrated photographic magnitudes have been

measured for all globular clusters observable at Mount Wilson. These investigations fill an important need.

In all branches of the solar and stellar work of the Observatory, the improved efficiency afforded by the use of aluminum instead of silver reflecting surfaces has been most marked. It has been of especial value for stellar spectroscopic investigations, the discovery of new clusters of extragalactic objects and the study of the forms of galactic nebulae. A striking illustration was the discovery by Dr. Duncan of the Whittin Observatory of Wellesley College of an outer ring on a photograph of the well-known Ring nebula in Lyra taken with the 100-inch telescope.

The solution of problems relating to the distances of the fainter stars, their distribution and the dimensions of our galaxy depends to a very large extent upon accurate measurements of stellar brightness and the evaluation of absorption due to cosmic dust and interstellar clouds. The catalogue of the photographic magnitudes of 2269 stars north of declination  $+80^\circ$  completed last year has now been supplemented by measures of the photo-visual magnitudes of a large number of stars brighter than magnitude 9.5 which will provide excellent standards of reference additional to those of the Polar Sequence. A study of these stars leads to the interesting conclusion that obscuring matter is present in the polar region in sufficient quantity to redden these stars by about 0.10 magnitude.

A marked relationship between the colors of stars and the zone within which extragalactic nebulae are not found or are few in number has been established by an investigation of the colors of stars in 30 Selected Areas. Conspicuous color excesses ranging upward to 0.8 mag. occur in regions where nebular counts indicate the presence of partial obscuration. Observations with the photoelectric photometer of B-type stars, which as a class are very distant and mainly confined to the neighborhood of the Milky Way, show that the amount of space-reddening per unit distance is considerably greater toward the center of the galaxy than in the opposite direction, and that absorption by interstellar dark matter becomes appreciable at a distance of 1000 parsecs, or not more than one-tenth the estimated distance to the galactic center.

Most of the stars which astronomers observe have high luminosities and lie at great distances from the earth. Comparatively few are known which belong to the extreme dwarf class with luminosities much lower than that of the sun and yet are so close as to be bright enough to be readily observable. Such stars usually have large proper motions, and a search for them is based upon this characteristic. Twelve stars have recently been found at Mount Wilson to have luminosities less than one-hundredth that of the sun, and two of these give out only one ten-thousandth of the sun's light. A star of especial interest is the white (high-temperature) dwarf Ross 627, with a luminosity slightly more than one two-thousandth that of the sun.

A study of the relative abundance of intrinsically faint stars based upon some 650 stars with modern parallaxes indicates that the total number in the whole sky with proper motions exceeding  $0''.5$  annually is about 2400.



As viewed from the earth, the stars with luminosities about one-hundredth the luminosity of the sun appear to be the most numerous.

Methods for deriving the average luminosities and distances of groups of stars from their motions are of great importance in studies of stellar distribution and provide standards of reference upon which many spectroscopic and photometric determinations of luminosity are based. A new method which has been developed and applied to stars of advanced type of spectrum gives results in good agreement with those derived by quite independent methods. They confirm the small range in the luminosities of the K-type giant stars and the existence of the sub-giant group of intermediate luminosity.

Extensive studies in stars of early spectral type of the lines of calcium and sodium, which are due to absorption by interstellar gas that does not share in the motion of the stars, have provided important material bearing on problems of stellar distances and luminosities and galactic rotation. Observations of spectroscopic binaries and other stars during the year have afforded conclusive evidence that certain additional lines discovered in the yellow and red portions of the spectrum are also of interstellar origin.

As in past years, investigations of variable stars have formed a considerable part of the work of the stellar spectroscopic department. Such stars, through their changes in spectrum, furnish valuable data regarding physical processes of radiation in stars in general; and certain classes, such as the Cepheids and the cluster-type variables, are of immense value for measurements of distances in the galactic and extragalactic universes. Curves of the radial velocities of 100 Cepheid variables with periods between 1.5 and 45 days have been completed, and the orbits of a number of Algol variables have been calculated. The spectra of many variable stars are under investigation with the microphotometer.

The large spectrographs at the coudé focus of the 100-inch telescope have been used chiefly for detailed studies of the spectra of bright stars. The high dispersion of the 15-foot spectrograph provides excellent material for measurements of the contours and total absorptions of spectral lines over a wide range of spectrum, a field which is now under active investigation. The 9-foot instrument with its greater efficiency in the ultraviolet is of especial value for the study of the H and K lines, and numerous stars of early and late spectral types are being investigated in this region. The remarkable spectroscopic binary  $\beta$  Capricorni has been observed extensively. The use of a large quartz prism in the 9-foot spectrograph has brought an important and very little studied region of the spectra of bright stars within the range of observation.

The possibility of sudden fluctuations in solar activity has long emphasized the importance of an unbroken record of various types of solar phenomena. Recently the Observatory has added to its routine program a continuous series of small-scale hydrogen spectroheliograms, made automatically on moving-picture film, for the purpose of detecting bright hydrogen eruptions—outbursts of intensely luminous gas, usually closely localized, which occur in the immediate neighborhood of sun-spots.

These rather rare phenomena have lately become of special interest because of several well-authenticated coincidences of hydrogen eruptions with radio fading and disturbances of the earth's magnetic field, and also because there is now rather strong evidence that the eruptions occur simultaneously in two or more spots with a frequency too great to be attributed to chance. If future observations confirm the present indications, the conclusion will be that the bright hydrogen eruptions, notwithstanding their localized appearance, are manifestations of some deep-seated phenomenon, and hence probably an important index of solar activity.

The large contribution made by the Observatory to the various programs of fundamental solar observations, several of which are cooperative, is illustrated by the diversity of the observational data quickly made available to others interested in solar problems. Duplicate spectroheliograms are sent to the Kodaikanal and Meudon Observatories; the numbers of sun-spots go weekly to Science Service; the positions and areas of spots, to the U. S. Naval Observatory for regular publication in the *Monthly Weather Review*; magnetic characters of spots are issued every 60 days in the *Publications of the Astronomical Society of the Pacific*; records of ultraviolet radiation and of bright hydrogen eruptions and the character figures of solar activity as indicated by calcium and hydrogen flocculi are forwarded to various Commissions of the International Astronomical Union; and, finally, the character figures of the earth's magnetic field, which are often dependent on solar phenomena, go to the Department of Terrestrial Magnetism of the Carnegie Institution for quarterly publication in *Terrestrial Magnetism and Electricity*.

The progress of the current sun-spot cycle is indicated by the average numbers of spots visible daily. For 1934, 1935, and the first half of 1936 the numbers are 1.0, 3.6, and 7.2, respectively. The maximum is probably not to be expected until 2 or 3 years from now. The magnetic polarities of the spots, as usual, have been almost invariably regular, the abnormal cases during the year amounting to only 2 per cent.

The great extent of infrared solar spectrum made accessible to observation by modern developments in photographic plates is under active investigation. The fundamental demand for precise standards of wave-length in this almost unknown region has been met by the publication during the year of values for 249 lines between  $\lambda 7000$  and  $\lambda 12,000$ . To  $\lambda 10,600$  the results are based on interferometer measures, and to  $\lambda 10,000$  appear to be reliable to 1 part in a million. The infrared limit now stands at  $\lambda 13,500$ . An extension of the *Revised Rowland Table of Solar Wave-Lengths*, which will begin at  $\lambda 6600$  and cover the entire infrared region, together with a map, is now in preparation. These important data will not only give a great deal of new information about the constitution of the sun but also, because of the great range in wave-length now accessible, provide abundant material for tests and applications of modern spectroscopic theory.

Perhaps the most spectacular of all solar phenomena are the eruptive prominences which rise from the photosphere with explosive violence. As compared with terrestrial motions the velocities are always high, and on

occasion the curved jets and streamers may reach an elevation of several hundred thousand kilometers in a few minutes time. The origin of the forces involved is still unknown, but some of the characteristics of the motions have now been learned. As stated in an earlier Report, the velocities of the ordinary eruptive prominences remain constant, usually for intervals of about an hour, then suddenly increase. During the year a second characteristic of the motions has been announced: The new velocity following a sudden acceleration is a small multiple of the preceding velocity. Two or three separate accelerations during the life of a prominence are not uncommon, and in the 40 prominences thus far measured in detail there are no exceptions not easily explained by special circumstances. One class at least of the much rarer sun-spot prominences seems also to follow these laws of motion. The import of these results is yet to be learned, but there can be little doubt that they are of great significance.

The work of the Physical Laboratory retains its close relation to the problems of the sun and the stars, and today has especially intimate connections with theoretical spectroscopy. As in recent years, much time has been devoted to the wave-lengths, intensities and temperature classifications of lines in the intricate spectra of the rare earths. A large number of additional faint lines of europium required for the completion of the analysis of the spectrum have been measured and much work has been done in acquiring data on Zeeman patterns for samarium, cerium and gadolinium. The analysis of singly ionized samarium, including more than 1200 lines involving 230 energy levels, has been completed and published. The photometric measurement of absorption lines in iron multiplets has been continued and data are now complete for 193 lines in 26 multiplets.

An examination of 60 spectrograms of 13 meteorites has led to the identification of 32 different elements, the more abundant of which belong to the first third of the atomic-number series. The presence of lithium, which has hitherto been doubtful, has been confirmed. The diversity of the elements present is much greater in the iron-nickel meteorites than in those of the stony type. Gallium and germanium, which are very rare on the earth but are observed in celestial spectra, occur in both types, while scandium, also rare, is found in the stony type. The results indicate that when adapted to quantitative analyses the method will be a valuable supplement to chemical and mineralogical methods.

#### STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his measurements of the general magnetic field of the sun and his observations with the spectrohelioscope. As Chairman of the Observatory Council of the California Institute of Technology he has devoted much time to the plans of the 200-inch telescope. Dr. Walter S. Adams, Director, has carried on investigations in stellar spectroscopy and the administrative work of the Observatory. During his absence in Europe at the meeting of the International Astronomical Union the administration was in charge of Dr. Frederick H. Seares, Assistant Director. Dr. Seares has continued his

photometric researches and the editorial supervision of the Observatory publications.

Dr. John A. Anderson has divided his time between laboratory studies of high-excitation spectra and his duties as Executive Officer of the 200-inch telescope project. Dr. Arthur S. King, Superintendent of the Physical Laboratory, has analyzed the spectra of rare earths and of meteorites, and in collaboration with Dr. R. B. King has measured the total absorption of lines in multiplets of the iron spectrum given by the electric furnace. Dr. Edwin Hubble has been engaged in the study of numerous problems relating to the distribution, luminosity and red shift of the extragalactic nebulae. Among other investigations in stellar spectroscopy Dr. Paul W. Merrill has given especial attention to the behavior of the interstellar sodium lines in the spectra of highly luminous stars and to the two recent novae. Mr. Harold D. Babcock is completing his catalogue of the wavelengths, intensities and identifications of lines in the infrared solar spectrum. He has also devoted much time to the supervision of the ruling machine. Professor Alfred H. Joy, Secretary of the Observatory, is preparing for publication his extensive measures of the radial velocities of the fainter Cepheids and has made many observations of other variable stars. Dr. Seth B. Nicholson has been in direct charge of investigations of sun-spot numbers, positions and polarities, observations with the spectroheliograph and the photographic photometry of solar spectrum lines. Dr. Francis G. Pease has given much of his time to the design of the mounting of the 200-inch telescope but has continued his observations with the 50-foot stellar interferometer. Dr. Adriaan van Maanen has added to his measures of parallax, chiefly of the fainter dwarf stars, and has investigated the frequency distribution of these stars on the basis of parallax and proper motion. Dr. Walter Baade has made photometric measures of faint reference stars and of variables in globular clusters and spectroscopic observations of Hind's variable nebula and the supernova in the extragalactic nebula NGC 4273. Dr. Roscoe F. Sanford has been engaged in the spectroscopic study of numerous variable stars, spectroscopic binaries, and stars with interstellar calcium lines and banded spectra. Dr. Edison Pettit has investigated the laws of motion in solar prominences with interesting results and has continued his measurements of ultraviolet solar radiation. Dr. Theodore Dunham jr. has been carrying on observations with the coudé spectrographs at the 100-inch telescope and studying the contours and intensities of the lines on the high-dispersion spectrograms. Dr. Dunham spent the months between February and May at Princeton University. Dr. Gustaf Strömberg has been occupied with studies of the distribution of stars according to luminosity and with methods for deriving absolute magnitudes from proper motions. He has also taken part in the stellar spectroscopic observations. Mr. Milton Humason has devoted most of his time to the difficult work of photographing the spectra of extragalactic nebulae, but in addition has investigated the spectra of many faint stars of exceptional interest. Mr. Ferdinand Ellerman has continued his solar observations and his general photographic work. Dr. Sinclair Smith has given much time to the design of portions of the 200-inch telescope, but

has also shared in the nebular investigations. Dr. Robert S. Richardson has been engaged in studies of solar activity and its relationship to terrestrial magnetic disturbances and radio transmission. Dr. Olin C. Wilson has shared in the stellar spectroscopic program, giving especial attention to interstellar lines and the contours and intensities of spectral lines in bright stars. Mr. Joseph Hickox has carried on solar observations on Mount Wilson, has continued his tests of photographic emulsions and prepared the large transparencies for the new astronomical exhibit.

In the Computing Division, Miss Louise Ware has nearly completed the measurement with the microphotometer of the intensities of spectrum lines at the sun's center and limb throughout the region  $\lambda 5400$ - $\lambda 6000$ . Miss Elizabeth E. Sternberg has measured sun-spot numbers and positions and prepared the extensive material dealing with the state of solar activity. Mr. Edward F. Adams has been engaged in the spectroscopic study of the sun's rotation period. He has also completed a long series of measurements from barographic records of the atmospheric pressure on Mount Wilson for the use of Professor S. Chapman. Dr. P. Th. Oosterhoff assisted Dr. van Maanen in his investigations of parallax and proper motion and carried on photometric studies until his departure for Holland in January. Dr. Boris Karpov continued this work after his appointment on February 15, 1936. Miss Myrtle L. Richmond has been engaged in measurements of ultraviolet solar radiation and in miscellaneous computations. Miss Mary C. Joyner has been associated with Dr. Seares in the derivation of standard stellar magnitudes, color indices and other photometric data. Mr. William H. Christie has carried on observations of stellar radial velocity and spectroscopic binaries and photometric measures of globular star clusters with the schafferkassette. Miss Cora G. Burwell has assisted and collaborated with Dr. Merrill in stellar spectroscopic investigations. Miss Ada M. Brayton has given much of her time to the compilation of the material on stellar luminosities and radial velocities and has aided in the reduction of stellar and laboratory spectrograms. Miss Elizabeth MacCormack continued her measurements of stellar radial velocities until her resignation on November 1, 1935. Miss Grace P. Wilson was appointed to this position on January 1, 1936. Miss Dorothy J. Carlson, now on full-time appointment, has assisted Dr. Dunham in the photographic photometry of stellar spectra and has also compiled and catalogued much of the observational material relating to nebulae. Mr. Wendell P. Hoge, who has been associated with the Observatory for many years, first as night assistant on Mount Wilson and later as a member of the Computing Division, retired on August 1, 1935. Miss Elizabeth R. Cornwall was appointed on February 1, 1936, and has aided Mr. Babcock in his studies of the infrared solar spectrum. Dr. R. M. Langer, special part-time assistant, has been associated with Dr. Hale at the Solar Laboratory in the investigation of the sun's general magnetic field. Miss Elizabeth Connor, Librarian, has continued to aid in the editorial work.

Dr. Henry Norris Russell, Research Associate of the Carnegie Institution and Director of the University Observatory, Princeton, spent the months of October and November 1935 in Pasadena. He gave particular attention,

among other investigations, to the term analysis of the spectrum of europium, basing his results upon photographs and measures made by Dr. King in the Physical Laboratory. Dr. Joel Stebbins, Research Associate of the Carnegie Institution and Director of the Washburn Observatory of the University of Wisconsin, and his associate Dr. Albert E. Whitford, National Research Fellow, carried on during the summer months of 1935 at Mount Wilson observations of the magnitudes and colors of extragalactic nebulae, B-type stars and globular star clusters with their photoelectric amplifier.

Dr. Frank E. Ross, of the Yerkes Observatory of the University of Chicago, continued on Mount Wilson his photography of the Milky Way and photometric observations. He also made tests of the correcting lenses designed to extend the field of the large reflectors. Dr. John C. Duncan, Director of the Whitin Observatory, Wellesley College, photographed a number of selected objects with the 100-inch telescope during August 1935, and returned to Pasadena in June 1936 to continue these observations. Dr. Fred E. Wright and Mr. Hamilton Wright made an extensive series of measures of the polarization of light reflected from features of the moon's surface with the 20-inch reflecting telescope. Dr. Rudolf Minkowski has spent the past year in Pasadena as a visiting investigator. A new spectrograph of his design with etalon plates for measuring by interference methods line-widths in nebulae with emission spectra has been completed in the instrument shop. Mr. A. D. Thackeray, Fellow on the Commonwealth Fund, has been engaged in a study of line-contours in the solar spectrum. Investigations of an allied character are being undertaken by Dr. G. F. W. Mulders of the Physical Laboratory, Utrecht, Holland, who has spent a portion of the year in Pasadena. Dr. Rupert Wildt, Fellow of the Rockefeller Foundation, who carried on solar and planetary observations, left the Observatory in February and returned to the eastern United States. Dr. Walter Albertson, National Research Fellow, has been actively engaged throughout the year in the term analysis of the spectra of rare earths. Dr. Robert B. King, of the Massachusetts Institute of Technology, collaborated with Dr. A. S. King during the summer of 1935 in a photometric study of the lines of iron multiplets. Mr. G. E. Kron of the Washburn Observatory assisted in the measures made by Dr. Stebbins and Dr. Whitford with the photoelectric amplifier. Mr. Horace Babcock carried on observations of the solar chromosphere on Mount Wilson during the summer months of 1935.

Many astronomers and scientists in other fields have visited the Observatory for briefer periods throughout the year.

### OBSERVING CONDITIONS

Observing conditions during the year were somewhat above the average, especially at night. Stellar observations were made on 310 nights, of which 213 were clear throughout. Solar observations were made on 295 days. The winter was mild, with little snow, and the total precipitation was 28.74 inches against a seasonal average of 31.49 inches. About 45 per cent

of the precipitation occurred in one storm between February 10 and 20. The maximum temperature was 93° F on June 20, 1936, and the minimum 14° F on March 25. The accompanying table shows the distribution of observing time with the 60-inch telescope throughout the year.

Month	Observations			Month	Observations		
	All night	Part of night	None		All night	Part of night	None
1935:				1936:			
July.....	26	4	1	January.....	12	13	6
August.....	23	5	3	February.....	8	7	14
September....	22	6	2	March.....	13	11	7
October.....	18	6	7	April.....	17	10	3
November.....	17	8	5	May.....	23	6	2
December.....	10	17	4	June.....	24	4	2
				Total.....	213	97	56
				Mean 24 years...	204	85	76

### SOLAR RESEARCH

Daily photographs with the spectroheliograph and observations of the numbers, areas, and positions of sun-spots have been continued. Measurements of ultraviolet radiation and of the horizontal intensity and direction of the earth's magnetic field have also been made regularly, and the magnetic character figures for each day have been supplied to the Department of Terrestrial Magnetism of the Carnegie Institution for publication in *Terrestrial Magnetism and Electricity*. Special attention has been given to the study of the intensities and contours of lines in the solar spectrum, at both the center and the limb of the sun, to the photometry of sun-spots, to the study of prominences, and to the intensity, duration, and spectral characteristics of bright hydrogen eruptions.

Daily observations of bright hydrogen flocculi were made during at least one hour each afternoon until the first of June, after which date these observations were extended to include the whole day. The results are communicated to Commission 11 of the International Astronomical Union as a part of the cooperative program of solar observation with the spectrohelioscope.

The positions and areas of sun-spots on 96 days have been supplied to the Naval Observatory for publication in the *Monthly Weather Review*, and reports of the number of sun-spots have been communicated to Science Service at Washington, daily until January 1936, and weekly since that time. Estimates of character figures of solar activity in 1935 were made by Nicholson and Miss Sternberg on 274 days for calcium flocculi and 268 days for hydrogen flocculi, and have been sent to Commission 10 of the International Union for publication in its Bulletin. Measurements of

ultraviolet radiation by Pettit and Miss Richmond were also published in this Bulletin for 234 days in 1935.

#### SOLAR PHOTOGRAPHY

Direct photographs of the sun have been made on 295 days with the 60-foot tower telescope by the solar observers Ellerman, Hickox, Nicholson and Richardson. The following plates have been obtained with the 13-foot spectroheliograph:

$H\alpha$ of disk, 2-inch image.....	473
$H\alpha$ of disk, 0.5-inch image.....	580
$H\alpha$ of spot-groups, 6-inch image.....	103
K2 of disk, 2-inch image.....	288
K of prominences, mainly 2-inch image...	341

Duplicate spectroheliograms have been supplied regularly to the Kodai-kanal and Meudon observatories as a part of the plan of cooperative solar observation.

Spectroheliograms of the disk and of prominences were made until March 1936 with a 6-inch visual objective of 18 feet focus and a field lens over the slit to obtain uniform illumination of the solar image. Since March 1, 1936, an off-axis 10-inch mirror has replaced the 6-inch lens. This gives uniform illumination over the image without the use of a field lens and requires no change in focus for different wave-lengths.

Since June 1, 1936, spectroheliograms in  $H\alpha$  of a solar image 2 cm in diameter have been made at intervals of 4 minutes throughout the day. Motion picture film is used in an automatic recorder which runs continuously. This automatic attachment is easily exchangeable with the regular plate holder and can be operated whenever the larger spectroheliograms are not being made. During June an average of 110 exposures per day was made with this equipment, thus providing a record of solar activity for about 8 hours daily.

During his stay at Princeton a 5-inch Schmidt camera was used by Dunham in connection with the 23-inch refractor in an attempt to photograph fine detail on the solar surface. After two reflections from unsilvered glass, the image was formed by the telescope close to the usual focal plane of the Schmidt camera and the enlarged image then formed at the conjugate focus. The increase in equivalent focal length was from 30 to 200 feet. This arrangement has the advantage over the usual negative enlarging lens of being nearly achromatic. Photographs taken with a motion picture camera showed excellent definition during the frequent periods of good solar seeing which sometimes persisted until the middle of the afternoon.

#### SUN-SPOT ACTIVITY

During the calendar year 1935, solar observations were made at Mount Wilson on 318 days, on 18 of which no spots were visible. The monthly means of the numbers of groups observed daily during the past two and one-half years are given in the following table:



Month	Daily number			Month	Daily number	
	1934	1935	1936		1934	1935
January.....	0.3	1.8	5.6	July.....	1.1	3.0
February.....	0.9	2.3	7.7	August.....	0.8	3.2
March.....	0.6	2.2	7.9	September.....	0.6	4.7
April.....	0.9	1.2	8.4	October.....	0.6	6.6
May.....	1.8	2.6	6.3	November.....	1.0	5.9
June.....	0.6	4.1	7.1	December.....	2.3	6.2
				Yearly average.....	1.0	3.6

No spots belonging with certainty to the old cycle have been observed since May 24, 1935. On the other hand, the number of groups of the new cycle (high-latitude spots) increased in the northern hemisphere from 17 in 1934 to 99 in 1935, and in the southern hemisphere from 35 to 116. The mean latitude of the spot-zones was 22°7'. Five groups with areas at least 1000 millionths of a solar hemisphere were observed during the calendar year.

The maximum of sun-spot activity in the last cycle was not sharply defined, the yearly means of numbers of groups observed daily being nearly the same for the four years 1926-1929. Although the activity during the last quarter of 1935 equaled the average of 1926-1929, it seems probable that the maximum of the present cycle will not be reached for two or three years. Since high and low maxima of alternate cycles seem to be a permanent characteristic of solar activity and since the maximum of 1928 was lower than that of 1917, the present cycle may be expected to be an active one.

#### SUN-SPOT POLARITIES

Systematic observations of the magnetic polarities of sun-spots have been made daily with the 150-foot tower telescope since 1915. Before January 1936, the magnetic polarities of all spots were obtained every day. Since that time, however, fewer determinations have been made, and the effort has been simply to observe the polarities of the spots in each group at least once. The accompanying table indicates the number of spot-groups classified from July 1935 to July 1936. "Regular" groups in the northern hemisphere are those in which the preceding spot had N (north-seeking), or positive, polarity and the following spot S polarity. In the southern hemisphere these polarities are reversed.

Hemisphere	Polarity		
	Regular	Irregular	Unclassified
North.....	125	2	58
South.....	141	3	49
Whole sun.....	266	5	107

## SOLAR ROTATION

A study of the effect of scattered light in the telescope and spectrograph on the spectroscopic measurements of solar rotation has been continued by Nicholson, Richardson, and E. F. Adams.

## INFRARED SOLAR SPECTRUM

The publication by Babcock, Miss Moore and Hoge of a list of infrared wave-lengths suitable for use as standards (*Mt. Wilson Contr.*, No. 534) has supplied a basis for further detailed study of this region of the solar spectrum. During the year, Babcock has continued work on the improvement of the wave-length scale beyond  $\lambda 11,500$  and its extension to the vicinity of  $\lambda 13,500$ . In spite of increased instrumental difficulties, it is evident that the accuracy is such as to make possible the identification of many solar lines as soon as more complete laboratory data are available.

An additional check on the reliability of the solar wave-lengths has been found in observations of the absorption band of oxygen near  $\lambda 12,600$ . The origin of this band as given by the measurements is in good agreement with that found by other observers, and certain known intervals among rotational levels in the molecule are closely duplicated even on these low-dispersion photographs.

Babcock and Miss Moore have been engaged in improving the estimates of intensities of the lines in this region, in segregating solar from atmospheric lines and identifying those of solar origin, and in preparing the material for publication. The new table begins at  $\lambda 6600$ , and in the region overlapping *Rowland's Table* will include many modifications of results for the weaker lines and some new identifications. The table will be supplemented with a map for which the spectrograms are being obtained with a 21-foot concave grating.

## ERUPTIVE PROMINENCES

Since Trouvelot made the first measurement on an eruptive prominence in 1885, data sufficient to indicate the character of the motion have been obtained for 40 different cases. A study of the first 24 cases by Pettit in 1920 gave as a first law: The motions of eruptive prominences are uniform, but usually change abruptly at intervals of about an hour.

A continuation of the study has now revealed a second law: When the velocity of an eruptive prominence changes, the new velocity is a small multiple of the old velocity; consequently the accelerations are multiples of the initial velocity.

An excellent illustration is prominence No. 22, observed on November 16, 1922:

Observed velocity	Computed velocity	O-C	Velocity factor	Acceleration	Acceleration factor
4.4	3.58	+0.8	1	3.58	1
6.6	7.2	-0.6	2	3.6	1
28.3	28.6	-0.3	4	21.5	6
57.2	57.3	-0.1	2	28.6	8
115.0	114.6	+0.4	2	57.3	16

The velocities are expressed in kilometers per second. The deviations from the law,  $O-C$ , are well within the errors of measurement. Only two of the 40 cases show any marked departure from the second law, and both of these are explained by an expansion of the prominence; measurements on the center of gravity remove the discrepancy.

A number of eruptive prominences were found to move for several hours with velocities of only 2 to 10 km/sec. Individual streamers and knots, however, were drawn into sun-spots or other centers of attraction with velocities of about 100 km/sec, thus indicating that in the main the eruptive force was counteracted by the attraction of localized areas on the sun. Such cases have been called "retarded eruptions."

Several eruptions of only a few minutes duration have been observed, but always with very high velocities, up to 520 and 525 km/sec in two cases. Both the brief and the retarded eruptions seem to obey the laws of the great eruptions. An eruptive prominence in the form of a detached cloud, which changed greatly in position angle, was found to move at an angle of  $50^\circ$  to the vertical. Of the 40 cases for which detailed data are available, only eight were associated with sun-spots. The others, whenever photographic observations are sufficient to permit a decision, seem to be connected with centers of attraction.

#### PROMINENCES OF SUN-SPOT TYPE

Sun-spots are not always accompanied by prominences, and a prominence of the sun-spot type (class 3) is relatively rare. Pettit finds that only 83 (1.3 per cent) occur on the 6151 prominence spectroheliograms (13-foot focus) taken between August 4, 1915, and January 1, 1936. With one exception all appear over very complicated spot-groups in either the early or the late stages of development. A few developed just after the spot-group had died out, and one or two just before the group appeared.

Sun-spot prominences show three subdivisions: class 3a, consisting of broken filaments moving radially into the spot area; class 3b, with chromospheric matter rising and falling in closed loops like a fountain; class 3c, lateral prominences, probably accidental, which, associated with 3a and 3b prominences, pour streamers into the spot.

The motions of the knots and streamers of ordinary active prominences in process of disruption by centers of attraction usually follow the two laws for eruptive prominences. The effect of substituting a spot for a center of attraction was first observed by Pettit at the Yerkes Observatory in the case of the 3c prominence of August 27, 1935. Measurements with a flexible scale along the curved streamers gave 22 time-distance plots which without exception agreed with the laws for eruptive prominences. It will be of interest to see if these laws, which seem to be general, also hold for classes 3a and 3b.

#### PHOTOELECTRIC MEASUREMENTS IN THE SOLAR SPECTRUM

Pettit has used the 20-inch telescope and 12-inch siderostat in combination with a quartz telephoto lens and an 8-inch concave-grating monochrometer of 21 feet focus to obtain amplified photoelectric measurements in the solar spectrum. A synchronized drive causes the spectrum to drift and

moves the plate on which the galvanometer deflections are recorded. Screens reduce scattered light to a negligible quantity. A cylindrical lens corrects the astigmatism of the grating and thus brings the dust-line focus into the focal plane. The sensitivity is such that the curves show lines as faint as 0 intensity on Rowland's scale.

A study of the H and K region gives for K a contour practically identical with that obtained photographically by Thackeray. At the center of the disk H has nearly the same form and depth ( $r = 0.08$ ) as K. The violet wing of K is somewhat the deeper, owing probably to the presence of strong absorption lines.

Drift-curves across the sun for chromospheric (reversed) H and K are quite alike, but very much flatter than those for the photospheric continuous spectrum at  $\lambda 3949$  and  $\lambda 4000$ . Drift-curves in H across sun-spots show the neighboring flocculi to be 42 per cent stronger than the surrounding photosphere. At the limb the excess is 36 per cent.

Similar measurements of  $H\beta$  reveal wings extending 17 A either side of the center. Although no filter was used, the contour of the line agrees substantially with Thackeray's photographic curve. Drift-curves across the sun in  $H\beta$ , like those of chromospheric H and K, are much flatter than those for the neighboring photospheric light.

#### ULTRAVIOLET SOLAR RADIATION

The ultraviolet solar radiometer has been operated by Pettit as in former years. The ratio of the intensity of sunlight at  $\lambda 0.5\mu$  to that at  $\lambda 0.32\mu$  continues to oscillate between 1.1 and 0.9. No large variation such as occurred at the corresponding phase of the last sun-spot cycle has yet appeared. The seasonal variation is still the most pronounced feature of the curve.

The reduction of the measurements of the ultraviolet energy-curve of the sun made on Mount Wilson in 1934 and 1935 yields the following results: (a) The solar energy outside our atmosphere is practically uniform from  $\lambda 0.38\mu$  to  $0.32\mu$ , in agreement with the Tucson work of 1931. (b) The intensity was 0.48 of the maximum at  $\lambda 0.48\mu$ , as against  $0.43\mu$  found at Tucson. (c) Throughout the ozone band there is a continuous drop, although the method of reduction presumably eliminates ozone absorption. (d) The atmospheric transmission coefficients are substantially the same as those obtained by Abbot. (e) The results for integrated light and for light from the center of the disk seem to be the same.

#### SIMULTANEOUS HYDROGEN ERUPTIONS

In preparing a catalogue of the flocculi shown on hydrogen spectroheliograms taken since 1917, Richardson found a number of plates showing bright eruptions over two widely separated spot-groups. Since such eruptions are not common, the repeated appearance of two on the same plate led to a special search for cases of this kind. After the exclusion of all questionable data there still remained not only many examples of two simultaneous eruptions, but also instances in which three and even four widely separated spots erupted at the same time. Thus for the years 1917-1935:

No. spots involved.....	2	3	4
No. of eruptions.....	21	8	5

The plates examined were taken on successive days, whereas an eruption usually requires 5 minutes or less to develop. Long series of exposures separated by brief intervals, made during the year in the study of radio fade-outs, have also been examined. These runs show three more instances of nearly simultaneous eruptions, the time intervals for the two spots being 24, 13, and 7 minutes, respectively.

A careful examination of probabilities indicates that chance coincidences will account for only 3 of the simultaneous eruptions in two spots and for none of those involving three and four spots. The results suggest that the eruptions originate in a deep-seated phenomenon which may manifest itself at widely separated points on the sun.

#### SOLAR ERUPTIONS AND RADIO FADE-OUTS

In October 1935 Dr. J. H. Dellinger of the Bureau of Standards reported four fade-outs of high-frequency radio transmission, each lasting about 15 minutes and occurring at intervals of approximately 54 days. To test whether the phenomenon might be connected with unusual solar activity, Richardson has examined the photographs of the routine solar program for the dates in question and for one other corresponding to an earlier fade-out which was subsequently reported. Several of the plates were taken while the fade-out was actually in progress. Meanwhile, weather permitting, special series of spectroheliograms have been taken at brief intervals near the date of each expected fade-out. The most striking result was obtained on April 8, 1936, when an abrupt radio fade-out, a sudden change in the direction and intensity of the earth's magnetic field, and an exceptionally brilliant sun-spot eruption all occurred simultaneously within a minute or so.

Three other instances also indicate a close correspondence between sun-spot eruptions and anomalies of radio transmission. On the other hand, a fine eruption was photographed on December 16, 1935; a fade-out might then have been expected, but none was reported.

#### HIGH-TEMPERATURE RADIATION AND MAGNETIC STORMS

It has been suggested that magnetic storms and auroras might be produced by high-temperature black-body radiation from small areas on the sun. Such areas might be expected to develop, if at all, at the time of a bright sun-spot eruption. An examination of some of our observational material by Richardson indicates, however, that such an explanation is very unlikely.

Many of the Mount Wilson spectroheliograms have been taken with two slits about 5 cm apart, one over the  $H\alpha$  or K2 line, the other over some part of the continuous spectrum. Two images are thus obtained simultaneously, one in the light of  $H\alpha$  or K2, the other in monochromatic light giving an image resembling a direct photograph of the sun. If bright eruptions are associated with black-body radiation of high temperature, the disturbed areas should also show on the monochromatic images taken with the continuous spectrum. An examination of several such plates showing strong eruptions in  $H\alpha$  or K2 revealed no trace of a corresponding area on the images produced by the continuous spectrum.

## GENERAL MAGNETIC FIELD OF THE SUN

In continuation of the measurement of the general magnetic field of the sun, Hale and Langer have designed and used a modified form of tipping-plate micrometer with devices to increase the speed with which settings can be made and to record the measures automatically. The plates measured were those of the series made at Mount Wilson in 1922-3 at the 150-foot tower telescope with the 75-foot spectrograph.

The errors of single settings with this instrument are several times larger than the residual average displacement, but appear to be distributed in a random manner. The mean values derived from numerous plates and many settings agree in sign but are considerably smaller than the results published by Hale, Seares and van Maanen. The displacement-curve is reasonably parallel to that of van Maanen. Past experience in measuring the absolute values of these minute quantities has shown differences between different observers of much the same order as those found in this case. Measures upon about 10 plates are required to show the change of sign between the northern and southern hemispheres, and although the results for 50 plates on the average have been combined for each point in latitude, approximately one point in five shows the reverse sign.

## LUNAR AND PLANETARY INVESTIGATIONS

## STUDY OF SURFACE FEATURES OF THE MOON

Dr. F. E. Wright and Hamilton Wright have continued visual measurements of the percentage of polarization in light from 24 selected areas on the moon's surface through two additional lunations. Nine lunations are now included in this series. Similar measurements have been completed on a number of terrestrial materials illuminated by sun's rays, especially on powders of different degrees of fineness. Special study is being made of the polarization phenomena produced by glass gratings and celluloid replicas in order to determine the significance of diffraction in the polarization of scattered light and its relation to negative polarization, observed both in moonlight and in light reflected by certain terrestrial materials.

The new mounting of the 20-inch telescope has been completed and will make it possible to resume measurements of polarization in moonlight with the aid of a thermoelement, polarization quartz spectrograph, and photo-electric cell equipped with a compound Wollaston prism of quartz.

Additional photographs of moon positives have been made on glass globes, but the results are not yet satisfactory because of the thin emulsion coat. A new series of globes is being coated at the Research Laboratories of the Eastman Kodak Company in preparation for further trials.

A new method has been developed for ascertaining the shapes, slope angles, and relative heights and depths of lunar surface features. For the purpose an accurate polar perspective projection chart is projected on lunar photographs taken with the 100-inch telescope; with the aid of the chart the angle which the sun's rays include with the normal to the moon's surface at any given point can be read off directly; also the angular and linear dimensions of any feature, such as a crater. If, for example, the angle of

elevation of the sun's rays is less than the slope angle of a crater wall, the wall casts a shadow; if it is greater, the slope is illuminated; if angle of elevation and slope angle are equal, grazing incidence is observed. The method is rapid and enables the observer to gather a surprisingly large amount of information on the shapes and dimensions of lunar surface features with fair accuracy and little or no computation.

#### POSITIONS OF SATELLITES AND ASTEROIDS

Positions of Jupiter's satellites VI, VII, and VIII, and of several asteroids have been determined by Nicholson and Miss Richmond from photographs with the 100-inch and 60-inch reflectors. An asteroid with an orbit inclined  $39^\circ$  to the ecliptic was found in declination  $+59^\circ$  by Hubble. The faint asteroid, Anteros, which has a very abnormal orbit and can approach very close to the earth, was followed with the 100-inch reflector until it reached magnitude 20.5.

### MISCELLANEOUS STELLAR INVESTIGATIONS

#### TRIGONOMETRIC PARALLAXES

Most of the objects now on van Maanen's program of measurement are faint stars of considerable proper motion. Twelve additional stars have been found with photographic absolute magnitudes fainter than  $+10$ ; Ross 64 has an absolute magnitude of  $+15.0$ , and Ross 92,  $+15.6$ . Ross 627, for which Humason has found a spectral type of A0, is a faint white dwarf with an absolute magnitude of  $+13.8$ .

The parallax determinations from plates taken at the Newtonian focus of the 100-inch telescope have been analyzed for systematic and probable errors. Apparently there is no evidence of systematic error. For 28 cases in which a sector had to be used to reduce the apparent magnitude of the parallax star, the probable error is  $0''.018$ , but only  $0''.006$  in the 55 cases where no sector was used. The large error occurring when the sector is used undoubtedly arises from the fact that the comparison stars are then at considerably larger distances from the central star. In the future it is planned to restrict the observations, with few exceptions, to stars for which no sector is necessary.

#### PROPER MOTIONS

The search for faint stars having considerable proper motions started by van Maanen and Willis has been finished by Oosterhoff. In 139 Selected Areas about 164,000 stars were examined with the stereocomparator and 772 were found to have proper motions exceeding  $0''.05$  annually. Of these, only 5 stars have motions exceeding  $0''.5$ .

In duplicating earlier photographs taken at the 80-foot focus of the 60-inch telescope van Maanen has found in 154 fields, each covering about one quarter of a square degree, 69 stars showing proper motions exceeding  $0''.05$ . Fourteen of these are companions of stars previously known to have proper motions as great as  $0''.5$ . Two stars of magnitudes 12.8 and 15.3 have proper motions of  $3''.01$  and  $0''.64$ , respectively.

Van Maanen has recently completed a discussion of the frequency distribution of intrinsically faint stars. Using material from several sources, he finds that the total number of stars in the whole sky with proper motions exceeding  $0.5$  is about 2400. For 651 of these, modern parallaxes are available. Such stars have been used to derive a formula for the mean parallax of stars of different magnitudes and proper motions. The material also provides an indication of the distribution around these means. If these results are applied to the stars having proper motions exceeding  $0.5$ , it is found that the maximum frequency falls at visual absolute magnitude  $+10.3$ . The proper motions exceeding  $0.1$  found by van Maanen, Willis and Oosterhoff, if used in the same way, also give a maximum at  $+10.3$ . Since in both cases a selection of the larger proper motions has favored the stars of faint absolute magnitude, and since the measures show the scarcity of large motions among the stars fainter than the fourteenth magnitude, the maximum of the frequency-curve of all these stars must be brighter than  $+10.3$ .

#### MAGNITUDES AND COLORS OF POLAR STARS

The completion of the photographic magnitudes for 2269 stars north of  $80^\circ$  declination was reported a year ago. The reduction of the short-exposure photographs giving the photovisual magnitudes of these stars to about 9.5 has now been finished by Seares and Miss Joyner. The calculations for the longer exposures, which will complete the program, are well advanced. These results will provide a large number of standards on the international system, additional to those of the Polar Sequence, with a photographic limit at 11.5 or a little fainter, and will greatly facilitate the use of large-field cameras in studies of the brighter stars.

The color indices for 271 stars of known spectral type define a relation between color and spectrum which, with the exception of the zero point, confirms that found from the comparison stars for Eros (*Mt. Wilson Contr.*, No. 415, 1930). For the polar region the mean color index of A0 stars is  $-0.04$ , with an uncertainty of 0.01 or 0.02; for the Eros stars the corresponding value is  $-0.14$ , a result confirmed by an independent investigation made by Dr. Ross at the Yerkes Observatory. The Eros stars are in apparently unobscured regions, and hence unaffected by selective absorption. Further confirmation is afforded by 170 stars of normal color in 19 Selected Areas, mostly between magnitudes 10 and 13.5. These stars give for A0 a mean color index of  $-0.12$ .

These results leave no doubt that for unobscured regions generally the mean color on the international system for A0 is close to  $-0.14$ . The algebraically larger value for the polar region is therefore strong evidence that the brighter stars in this region—those having H.D. spectra—show a mean color excess of about 0.10 mag. This conclusion is in harmony with the fact that direct photographs of the region (galactic latitudes  $18^\circ$  to  $38^\circ$ ) show traces of obscuration and that the counts of extragalactic nebulae are below normal.

Photoelectric measures of 30 stars of the North Polar Sequence by Stebbins and Whitford have given an independent check on the standards of the international system. This work is being continued.



## SELECTIVE ABSORPTION OF STARLIGHT

The colors of 454 stars in 30 Selected Areas, limiting magnitude 13.5 photographic, have been studied by Seares from the standpoint of selective absorption produced by interstellar clouds. The criterion for selective absorption is an excess of color over that inferred from the spectral types of the stars. The observed colors were obtained from the photographic and the photovisual magnitudes of the stars, all on the international system. The mean values of the color excess for groups of eight or ten stars show the following characteristics:

(1) All Areas within the zone of avoidance for extragalactic nebulae or in regions of partial obscuration as outlined by Hubble's counts of nebulae, 15 fields in all, show a conspicuous color excess.

(2) Eight Areas in higher latitudes also show color excess, smaller in amount but in most cases apparently definite. A sporadic region of low nebular density occurs within a few degrees of each of these fields.

(3) Nineteen Areas include groups of stars that are normal in color.

(4) Twelve of the 23 Areas showing color excess also include groups of stars that are normal in color.

(5) The mean color excess for 185 stars in 23 Areas is 0.5 mag., with a maximum of 0.8 mag. for a group of 13 stars in Area 40; for 99 additional stars in 10 of these Areas the mean color excess is 0.2 mag.

(6) The color excess increases as the galactic latitude of the fields decreases. Since all but one of the fields showing color excess fall within an interval of  $150^\circ$  in longitude, and none of them is very close to the direction of the galactic center, the data are not suitable for a discussion of the variation of color with longitude.

The results indicate that for any field in which the counts of extragalactic nebulae are below normal, an excess of color is to be expected for at least part of the stars in the field. Certain fields obscured by very dense clouds seem to provide exceptions to the general rule.

## GLOBULAR CLUSTERS

Stebbins and Whitford have finished the work on the colors of globular clusters. When the inferred distances in the general system of globular clusters are revised on the basis of the absorption indicated by the measured space-reddening, the overall diameter of the galaxy is reduced by about one half, or to 30,000 parsecs, which is of the same order as that of the Andromeda nebula. The discrepancy in size between our galaxy and other systems is therefore largely removed.

Baade has finished his investigations of two of a selected list of the fainter globular clusters whose distances are regarded as still uncertain. The moduli of distance, derived from cluster-type variables, are  $m - M = 16.95$  for NGC 5634 and 17.46 for NGC 6229.

Christie has completed his measures of the integrated magnitudes of 67 globular clusters, using a schaffierkassette with a variable throw attached to the 10-inch Cooke photographic refractor. Discussion of the data has been deferred pending attempts to measure a few very difficult objects which are of unusual interest.

### COLORS OF B-TYPE STARS

Stebbins and Whitford have continued color measurements of B-type stars in different galactic longitudes. They find that the amount of space reddening per unit distance is considerably greater toward the galactic center than toward the anti-center. From the distribution of colored B stars in the star clouds of the Milky Way they conclude that absorption by interstellar dark material is already significant at one thousand parsecs, not more than a tenth of the estimated distance to the galactic center.

### DISTRIBUTION OF ABSOLUTE MAGNITUDES

Strömberg has applied to stars of spectral types G8 to K2, brighter than apparent magnitude 5.8, his new method of determining the distribution of absolute magnitudes in a group of stars from their radial velocities and proper motions. The motions are projected on several fixed axes, each of which defines two polar areas and a corresponding equatorial zone. The radial velocities of the stars in the two polar areas give the distribution of the linear velocities projected on the axis, and the proper motion components in the equatorial zone give the corresponding distribution of angular velocities. These have all been reduced to correspond to a common apparent magnitude. The unknown distribution of absolute magnitudes is determined from a solution of an integral equation involving the unknown and the two known distributions.

When the method is applied to the K stars three independent determinations of the luminosity distribution, corresponding to velocity components along three mutually perpendicular axes, are found to agree well with one another and with the distribution of the spectroscopic absolute magnitudes. A remarkably small dispersion is found for the normal giants, and definite evidence for the existence of the group of subgiants with absolute magnitudes between +1.5 and +3.4.

New methods have also been developed by Strömberg for deriving the absolute-magnitude distribution of the supergiants, a problem which has presented great difficulties on account of the extreme smallness of the proper motions.

### STELLAR INTERFEROMETER

Pease has given considerable time to observations with the 50-foot interferometer, but the extremely exacting requirements of this instrument in the way of stellar definition have prevented many measurements of the diameters of stars. The best observations of  $\alpha$  Orionis were made on November 15, 1935, when extrapolated readings gave a mirror-separation of 13 feet, corresponding to an angular diameter of 0''.035. The actual value was probably slightly less because the visibility of fringes on standard reference stars was somewhat below normal.

### STELLAR SPECTROSCOPY

Spectroscopic observations of Nova Herculis 1934 and of Nova Lacertæ 1936 have been important features of the year's work in this department. More than 230 photographs of the spectrum of Nova Herculis were obtained in the 18 months after its discovery, and observations of the early stages

of the spectrum of Nova Lacertæ were continued on consecutive nights for as long a period as possible. The complete discussion of this valuable material will require much time, but should yield very extensive data on the physical behavior of these important stars.

Two additions to the instrumental equipment have been the 2-prism spectrograph with interference attachments designed by Minkowski, and the large crystalline quartz prism which is utilized in the coude spectrograph of the 100-inch telescope in accordance with a design by Dunham. The first of these instruments, described elsewhere, is planned chiefly for nebular spectrophotometry, but has proved valuable for direct spectrophotographic work because of the absence of lenses, its excellent field and high efficiency. The quartz prism has an angle of  $30^\circ$  and an aperture of  $4\frac{1}{4}$  inches. It is aluminized on its vertical face and is used in conjunction with an off-axis mirror of 9 feet focal length, which serves both as collimator and camera. The spectrum is formed in the plateholder opening of the regular coude spectrographs. Spectra of several stars with a linear scale of 8.2 Å per mm at  $\lambda 3200$  have been photographed as far as  $\lambda 3050$  with this instrument. The definition is excellent over a range of about 400 Å, and the many lines which are shown are being studied and identified by Dunham. All the glass prisms near the slit formerly used for the iron comparison arc and the calibration spectrum have been replaced by similar prisms of quartz.

The Schmidt camera with a focal length of 32 inches for use with the grating has been installed at the coude focus and gives excellent definition. Portions of a similar camera with a focal length of 73 inches have been completed. A device containing three polarizing prisms has been installed above the slit of the coude spectrographs to reduce the intensity of the sun's image and make possible a direct comparison with the same instrument of the intensities of absorption lines in the spectra of the sun and the brighter stars.

A total of 1245 spectrograms has been obtained with the various instruments during the year. The 3-prism ultraviolet spectrograph has been used extensively because of its efficiency in the region of the H and K lines.

#### RADIAL VELOCITIES

Measurements of the radial velocities of stars in the regular observing list, including, among many others, stars in the Selected Areas and standard velocity stars, have been continued actively throughout the year. This work has been carried on mainly by Sanford, Wilson and Christie with the assistance of Miss MacCormack, Miss Brayton and Miss Wilson. A series of spectrograms of  $\alpha$  Boötis has been obtained by Adams with the 15-foot coude spectrograph for the purpose of testing the precision of measurement possible with this instrument and the constancy of the star's radial velocity.

The radial velocities of the fainter Cepheid variables have been under investigation by Joy for several years, and the velocity-curves of 100 of these stars with periods between 1.5 and 45 days have been completed and are being prepared for publication. Sanford has observed the two Cepheids FF Aquilæ and Y Ophiuchi, both of which appear to show marked changes

in the form of their velocity-curves. He has also calculated approximate spectrographic orbits for the five Algol variables TT Herculis, UX Herculis, SX Hydræ, TT Hydræ and WZ Ophiuchi. Observations of Boss 1074 with a long period of velocity-variation have been continued regularly. Christie has calculated and published the velocity-curves of 16 spectroscopic binaries, mainly of spectral type K, with periods between 106 and 4000 days, and has continued his observations of  $\zeta$  Aurigæ and the interesting system H.D. 198287-8, which shows a departure from the previously determined motion of the "center of mass."

A star of unusual spectroscopic interest is  $\beta$  Capricorni, now under observation with the 9-foot coude spectrograph. This star has a composite spectrum and a variable radial velocity investigated by Merrill many years ago. At the request of Dr. Luyten of the University of Minnesota, three coude spectrograms were obtained and sent to him for examination. He found that the H and K lines showed velocities which varied rapidly and differed greatly from those given by the lines of the bright G-type star. Further observations have confirmed these results and added a few other lines which give velocities agreeing with those from H and K. Doubtless these lines belong to an A-type companion of the principal star, but the persistence of the G-type spectrum in the ultraviolet, the character of the spectrum near H and K and the behavior of the hydrogen lines present interesting problems. The star  $\beta^1$  Cygni, also of composite spectrum and very similar to  $\beta$  Capricorni, shows no difference between the velocities given by the K line and the lines of the G-type star.

#### LONG-PERIOD VARIABLE STARS

Our knowledge of the spectra of long-period variables near their light-minima is very meager, chiefly because at this phase exposures with the regular stellar spectrographs must be extremely long. A brief reconnaissance of the spectra of variables of classes Me and Se during their fainter phases has therefore been made by Merrill with the low-dispersion nebular spectrograph (*Mt. Wilson Contr.*, No. 539). These small-scale photographs emphasize in a striking manner the fact that the apparent distribution of energy in the spectra of Me variables differs very greatly from that of Se variables and of the black-body spectrum, the intensity between  $\lambda 4220$  and  $\lambda 3970$  being unduly high. The effect is probably caused in large part by the heavy absorption of titanium oxide at longer wave-lengths. Among the results obtained are the following:

- (1) Large changes in total light may occur without marked changes in the absorption spectrum.
- (2) The behavior of the chief bright lines (other than those of hydrogen) is remarkably alike in Me and Se spectra.
- (3) Not all long-period variables have observable "companion" spectra near minimum light.
- (4) A peculiar band-head near  $\lambda 4415$  in the spectrum of  $\chi$  Cygni calls for further observation.

Additional investigations on stars of this class have included a study of the structure of the emission lines in the spectrum of  $\alpha$  Ceti with high dis-

persion, and observations of U Canum Venaticorum by Joy and Merrill throughout its cycle of light-variation of 195 days.

#### INTERSTELLAR LINES

The study of the lines which appear in the spectra of very distant stars and are due to absorption by interstellar gases has included two investigations. The first, by Sanford, has dealt with the H and K lines of calcium in the spectra of stars of types O and B and those showing c characteristics to type A2 inclusive. About 240 stars have been observed, and correlations of velocity with distance, color excess and galactic longitude are being investigated. Measurements of the intensities of H and K are being made on microphotometer tracings by Sanford with the assistance of Miss Wilson.

Similar studies of the detached (interstellar) D lines of sodium have been made by Merrill, Wilson and Miss Burwell in the spectra of over 200 of the same stars investigated by Sanford. Numerous intercomparisons of the behavior of interstellar calcium and sodium are thus made possible.

Further strong evidence that the lines  $\lambda\lambda 5780$  and  $6284$ , found by Merrill to be abnormal in character and probably interstellar in origin, do not show the velocities given by stellar lines but do show those given by the detached sodium lines is afforded by an investigation by Merrill of the spectroscopic binary Boss 6142. A revised orbit of this star calculated by Sanford from observations extending over the interval 1911 to 1934 has aided in this comparison. Merrill has also compared the wave-lengths of these lines in groups of stars in which the stellar velocities differ by more than 20 km/sec from those yielded by the interstellar sodium lines. The accordance of the wave-lengths of these lines on the assumption that they are interstellar in character and their discordance on the assumption that they are stellar show that the atoms in which the lines originate do not move with the stars but do yield nearly the same displacements as interstellar sodium atoms.

#### NOVA HERCULIS 1934

The results of two investigations of the spectrum of Nova Herculis have been published during the year. One of these, by Adams and Joy, deals with the principal spectral changes between March 1935 and February 1936 when emission bands had become the prominent features of the spectrum. Forbidden iron lines [*Fe* II] became conspicuous in April 1935 and were displaced about 30 km/sec to the violet as compared with lines of *Fe* II. In May the nebular spectrum became fully developed. Changes in the widths, displacements and intensities of the bright bands between  $\lambda 3750$  and  $\lambda 6600$  were investigated and classified. A catalogue gives the identification of a large proportion of these bands and progressive changes in wave-length and intensity.

Merrill has studied the spectrum in the region  $\lambda 5150$ - $\lambda 6550$  with a plane-grating spectrograph. Especial attention has been given to measurements of the edges, maxima and centers of the [*O* I] lines  $\lambda\lambda 6300$ ,  $6363$ ,  $5577$  (the auroral line) and several lines of *Fe* II. The widths of these lines increased gradually from an equivalent of 540 km/sec to 700 or 800 km/sec and their structures underwent remarkable changes. Among the absorption lines

observed were those of  $\text{Na I}$ ,  $\text{O I}$ ,  $\text{He I}$  and of half a dozen ionized elements. The D lines of sodium showed clearly over a long period the complex behavior of various components, and on a few of the earlier plates weak interstellar lines were measured.

The chief facts concerning the widths and displacements of both bright and dark lines appear favorable to the commonly accepted hypothesis of an expanding atmosphere, although many details are puzzling. This hypothesis may take one of two forms depending on whether the emission of atoms is assumed to be instantaneous or continuing. Merrill suggests that the comparative behavior of permitted and forbidden lines may largely be explained by the inability of the atoms directly in front of the star to produce forbidden lines in absorption. On this interpretation the radial velocity of the star as a whole was  $-4$  km/sec, and the emitting and absorbing gaseous shell had a radius about twice that of the photosphere. It is suggested that the expanding atmosphere of a nova may arise from an explosive pulse which drives off matter in a condensed or incompressible state from which gaseous atoms later evaporate.

#### NOVA LACERTÆ 1936

The spectrum of this star during the short interval between June 18, the date of its discovery, and July 1 underwent some very interesting changes. The first observations showed a series of broad absorption components of hydrogen and a few other lines with a displacement to the violet corresponding to a velocity of approach of nearly 1200 km/sec. This component persisted throughout successive observations, and with some irregularities the velocity increased, at first rapidly and then slowly, until it reached a value of  $-2570$  km/sec on July 1. For a short period beginning about June 27 it became a sharp narrow absorption line which later disappeared.

A vague short-lived component yielding a velocity of about  $-700$  km/sec was seen on June 19 and 20. On June 20, however, another strong component appeared with a velocity of nearly  $-2800$  km/sec. This velocity increased rapidly and when last measured on June 24 amounted to nearly  $-3500$  km/sec, the highest velocity ever observed in a galactic nova.

The emission bands in the spectrum, relatively inconspicuous at first, increased rapidly in intensity. The width of the hydrogen band  $H\beta$  was about 50 angstroms. The chief elements represented by bright bands between  $\lambda 3850$  and  $\lambda 5000$  were  $\text{H}$ ,  $\text{Ca II}$ ,  $\text{He I}$  and  $\text{Fe II}$ .

Interstellar absorption lines of calcium and sodium are prominent in the spectrum of this star and give a radial velocity, corrected for the solar motion, of  $-13$  km/sec. Measures of the intensities of these lines by Wilson and Merrill, reduced by a calibration-curve based upon their results for a large number of stars, indicate a distance of 800 parsecs (2600 light-years) and an absolute magnitude at maximum of light of  $-7.2$ .

#### OBSERVATIONS OF FORMER NOVÆ

Humason has photographed during the year the spectra of 5 former novæ. Recent records of 14 of these objects are now available. Joy has continued his observations of Nova Ophiuchi (RS 1933) in the spectrum of which the solar coronal lines were observed about two years ago.

Wilson has used measures of the interstellar K line of calcium to derive absolute magnitudes at maximum of  $-9.9$  for Nova Aquilæ 1918, and of  $-7.9$  for Nova Cygni 1920. The former value is of very low weight, but in rough agreement with that of  $-9.2$  determined by Hubble and Duncan from the rate of motion of the expanding shell.

#### COMPARISON OF SPECTROSCOPIC AND TRIGONOMETRIC PARALLAXES

Adams and Joy have compared the spectroscopic parallaxes given in *Mt. Wilson Contr.*, No. 511 with the uniform system of trigonometric values in Schlesinger's recent catalogue. Of these, 1825 stars were found to be common to both lists. The average difference between a single trigonometric determination and a spectroscopic estimate is  $0''.011$ . The systematic differences, spectroscopic *minus* trigonometric are:

Main sequence .....	+0''.0002
Giants .....	-0''.0003
Supergiants .....	+0''.0015

#### STELLAR SPECTROPHOTOMETRY

Measurements of the contours and the total absorption in the lines of stellar spectra with the microphotometer form an important part of many of the stellar spectroscopic investigations. The spectrograms studied in this way are chiefly those obtained with the coudé spectrographs, the 3-prism ultraviolet instrument and the plane-grating spectrograph.

Dunham has continued his observing program with the coudé spectrographs in an attempt to secure a set of reliable photometric plates covering typical stars throughout the spectral sequence. The measurement of the intensities of absorption lines has required few changes in either the microphotometer or the device for the reduction of photometric tracings.

Our ignorance of the relative intensities of the individual lines within most multiplets is at present the most serious obstacle to an experimental test of the theory of stellar atmospheres. Theory has not developed to the point where it can compute these intensities with nearly the required accuracy. An important start has been made on the extensive undertaking of measuring multiplets in the laboratory by Robert King and A. S. King, and by Minkowski. While waiting for these data to accumulate, an attempt is being made to determine the intensities within each multiplet by comparing the component lines in the spectra of different stars. A general solution is being made, regarding the apparent turbulence and the damping constant as unknown and variable from star to star. Unsöld's recent work shows that collision damping is much more important than has been realized, and may even exceed radiation damping in the relatively dense atmospheres of dwarf stars.

Miss Carlson has organized and tabulated a large amount of spectroscopic data which have been invaluable in the course of this work.

A study of the absorption lines in the spectrum of  $\alpha$  Cygni made by Wilson with the microphotometer indicates that the width of these lines is such that on high-dispersion spectrograms the contours may be obtained

essentially undistorted by finite resolving power. The  $Fe\ II$  lines can be represented with surprising accuracy by formulæ of the type

$$r = 1 - De^{-a(\Delta\lambda)^2},$$

where  $D$  is the depth and  $a$  is a constant.  $D$  and  $a$  both appear to be correlated with the total absorption of the lines.

Wilson has partially completed a quantitative investigation of spectral changes in the variable star RR Lyræ with a period of 0.57 days. Satisfactory curves have been obtained for the lines of  $H$  and  $Ca\ II$ , and the weaker metallic lines are now being studied. The hydrogen lines reach their maximum intensity when the star is brightest, while the opposite is true of  $Ca\ II$  and the other metallic lines.

In two *Mount Wilson Contributions*, Nos. 540 and 541, E. G. Williams of Cambridge gives the results of his investigation, made while a Commonwealth Fellow at Mount Wilson, of the equivalent widths of all measurable lines in the region 3820-4922 in the spectra of 84 O- and B-type stars. Systematic effect of dispersion on the total absorption in lines is found to be negligible except in the case of weak lines with very low dispersion. The relative intensities of the Balmer lines of hydrogen,  $H\delta$  to  $H\alpha$ , agree well with the predicted values of Pannekoek and Verwey, but the actual contours do not fit the theoretical ones, the observed lines having too much light at the center.

These results have been applied to a reclassification of B-type stars. Ratios of seven groups of lines of various ionized elements have been determined which are suitable for classification purposes. They are so arranged that type B2 agrees with the same type on the Victoria system. When the stars are grouped according to absolute intensities of the lines, three luminosity groups appear: giants, stars of intermediate luminosity and dwarfs. Lines of hydrogen and helium are weakest in the giants, while practically all other lines show the opposite effect. It is owing to these facts that the grouping according to absolute magnitude can be made.

Williams has used data on proper motions, radial velocities and galactic rotation in combination with his measures of the intensity of the interstellar K line to deduce a relationship between K-line intensity and distance. The results confirm his groupings according to luminosity, which depend entirely upon spectral characteristics.

#### MISCELLANEOUS

A spectrogram by Humason of the faint star of large proper motion, Ross 627, shows it to be a white dwarf. Its spectral type is estimated to be about A0, with the wide and shallow hydrogen lines characteristic of this class. On the basis of the absolute parallax of  $+0''.089$  measured by van Maanen, the star is one of the three faintest white dwarfs known.

Several years ago the absorption lines of hydrogen in the spectrum of P Cygni were observed to be double. Recently Wilson has found that the two components vary radically in their relative intensities and possibly in their displacements as well. The helium lines probably show the same behavior.



Sanford and King have photographed the band spectrum of cyanogen in the electric furnace as far as  $\lambda 9000$  for comparison with these bands in N-type stars. The stellar plane-grating spectrograph was used so that the scale and resolving power are the same for the spectra compared.

In a previous classification by Humason of the spectral types of faint stars in the Selected Areas, 45 stars in Area 98 were estimated from slitless spectrograms as belonging to type B. This group comprised 34 per cent of the stars classified in Area 98, and 44 per cent of all the stars classified as B in the 115 Areas observed. Because of the difficulty of distinguishing between types B and F on slitless photographs unless the H and K lines are visible, this group of stars has been reobserved by Humason with a slit spectrograph. The observations show that with the exception of 4 stars all should be classified as of type A or F. This result indicates that of the 4066 stars classified in 115 Areas less than one per cent belong to type B.

Christie has made a study of the curvature of spectral lines produced by auto-collimating prismatic spectrographs and has shown the error of the assumption made by some observers that no curvature is present with such instruments. He has measured and calculated the effect for the coude spectrographs used with the 100-inch telescope.

## GALACTIC NEBULÆ

### DIRECT PHOTOGRAPHY

Photographs of the Ring Nebula in Lyra made by Duncan with the 100-inch reflector reveal a faint, hitherto unrecorded envelope, roughly circular in outline and about twice the diameter of the well-known ring. The envelope appears with a 30-minute exposure on an Imperial Eclipse plate and is confirmed by an exposure of 58 minutes, but is not shown with one of 15 minutes. The efficiency of the aluminum coating of the mirrors in reflecting ultraviolet light may have aided materially in the discovery.

Nova Lacertæ 1936, photographed on June 26, 1936, with exposures of 3 seconds to one hour, showed no trace of nebulosity. Photographs of the dark nebulosities Barnard 92 and 93, also by Duncan, reveal no conspicuous changes during the interval 1922 to 1936.

### VARIABLE NEBULOSITIES

The variable nebulosities, NGC 1555 (Hind's nebula near T Tauri), 2261 and 6729, have been under observation by Baade and Hubble. More or less continuous records covering periods of 25 years for NGC 1555 and 16 years for each of the other two objects are now available at Mount Wilson. The changes in NGC 1555 have been the slowest, but about 1920 the region of the knot D in Pease's diagram (*Mt. Wilson Contr.*, No. 127) began to brighten and can now readily be seen in the telescope. A weak spectrogram by Baade shows a faint continuous background with indications of emission lines. Much of the variation in all three of these nebulosities is provisionally attributed to patches of obscuration—dark clouds or, in some cases, possibly shadows of clouds—moving over the pattern of luminous details.

## STUDY OF NEBULAR EMISSION LINES BY INTERFERENCE METHODS

A new spectrograph designed by Minkowski for the study of the widths of emission lines by interference methods has been completed and tested. The instrument can be used at the Cassegrain focus of either of the large reflectors and will be employed by Minkowski and Baade to continue investigations begun by them at the Hamburg Observatory.

Although the slit is 1.5 inches long, there is no vignetting. The collimator is an off-axis mirror and the camera ( $f/3$ ) is of the Schmidt type; focal lengths are 32 and 6 inches, respectively. Dunham's system of working off-axis keeps the plate-holder out of the incoming beam. The two  $60^\circ$  prisms are of Jena F2 glass. In addition to a glass etalon of the usual type, two quartz etalons have been kindly lent by Professor P. P. Koch of Hamburg. The dispersion is 130 Å/mm at  $H\beta$  and 80 Å/mm at  $H\gamma$ . The definition is excellent over the observed range,  $\lambda 6800$  to about  $\lambda 3700$ , where the spectrum is limited by absorption in the prisms.

Preliminary exposures on the planetary NGC 6543 show that in the neighborhood of the nucleus the lines are clearly double, with a separation of about 0.5 Å, thus suggesting that the planetary is expanding.

## EXTRAGALACTIC NEBULÆ

The preliminary survey of nebulae, made for the purpose of analyzing the material and selecting the most effective fields of investigation with large reflectors, is now complete. Detailed investigations of conspicuous, individual nebulae are strengthening the foundations of the subject and providing definitive revisions of criteria for statistical studies.

## A NEW CLUSTER OF NEBULÆ

A new faint cluster of nebulae, Hydra No. 1, has been found by Hubble, centered about  $5'$  north and  $4'$  following NGC 2716, at  $\lambda = 194^\circ$ ,  $\beta = +30^\circ$ . Long exposures show about 200 nebulae within a circle  $5'$  in diameter, the fifth brightest being  $\text{pg. } m = 18.7$ , or about 0.5 mag. fainter than the fifth nebula in Boötis No. 1 and in Ursa Major No. 2, where apparent velocities of the order of 40,000 km/sec have been measured. An unsuccessful attempt by Humason to observe the red shift in the new cluster has led to the design of a more efficient spectrograph. This instrument, which is also adapted to the study of spectroscopic rotations, is now being constructed.

## MAGNITUDES AND COLORS OF NEBULÆ

The urgent need for a definitive scale of nebular magnitudes has been supplied by the accurate, photoelectric measures of Stebbins and Whitford. Whitford, using the 10-inch Cooke refractor, has determined integrated magnitudes of 11 of the brightest nebulae, which are too large for measurement with the reflectors. The results ( $\text{pg. } m = 4.5$  to  $9.4$ ) are especially important because these nebulae are mainly the neighboring well-known systems which serve to calibrate methods for investigating more distant regions of space.

Stebbins has reduced the measures of more than 150 nebulae made by himself and Whitford with the large reflectors. The results include integrated

magnitudes of 120 nebulae ranging from  $pg. m. = 9.5$  to  $13.6$ . The systematic correction to the magnitudes of the Harvard survey of bright nebulae is about  $-0.1$  mag. at  $m = 13$ . About 50 of the nebulae are in the Virgo Cluster ( $Dec. = 12^\circ \pm$ ) and form the skeleton of a standard sequence accessible to observers in both hemispheres.

The colors of about 100 nebulae were also derived. They exhibit a considerable range but, in the mean, vary progressively with nebular types. Comparisons with the (presumably dwarf) spectral types determined by Humason indicate persistent color excesses in all nebulae except the late-type spirals (see following table). The colors now available are not conspicuously dependent on galactic latitude, although they seem to show some space-reddening which originates within the galactic system.

#### RADIAL VELOCITIES AND SPECTRAL TYPES OF NEBULAE

Humason has published a list of apparent radial velocities and spectral types of 100 extragalactic nebulae which have been collected during the last five years. The data include 56 isolated nebulae and members of 5 groups and 6 clusters.

The mean spectral type (of the nuclear region) varies regularly with the nebular type, in a manner which parallels the variation in color derived by Stebbins and Whitford. The data are as follows:

<i>Type</i>	<i>Spectrum</i>	<i>No.</i>	<i>Color Class</i>	<i>No.</i>
E .....	G3.6	66	g6	31
Sa, SBa .....	G3.4	30	g5	13
Sb, SBb .....	G1.6	21	g4	12
Sc, SBc .....	F8.8	19	f7	37

The color classes are on the scale for giant stars (objects at  $\beta > 20^\circ$  are omitted), while the spectral types presumably are those of dwarfs.

Humason has measured velocities of 24 nebulae during the year. Emphasis was placed on the nearer, resolved nebulae in the general field, for the purpose of deriving an improved value for the motion of the galactic system relative to the nebulae.

#### SHORT-PERIOD CEPHEIDS IN IC 1613

Investigations of individual nebulae are represented by Baade's study of short-period Cepheids in IC 1613, the most distant known member of the Local Group. A series of plates with the 100-inch telescope, on 14 consecutive nights of good seeing, furnished data for Cepheids with periods less than 15 days (the limit of previous studies). Complete light-curves are now available for all cases in which  $P \leq 5$  days. Variables with shorter periods down to about 2 days were found, but they are recorded only near their maxima.

#### ENERGY DISTRIBUTION IN SPECTRA OF ELLIPTICAL NEBULAE

Elliptical nebulae, which are unresolved, are generally assumed to be composed of stars, but no definite proof has yet been found. Smith has investigated this problem by comparing the energy distribution in the continuous spectra of nine elliptical nebulae with that of stars of comparable types

(dG9 to dK2). The spectra covered a long range ( $\lambda 3100$  to  $\lambda 8000$ ), but were necessarily on a small scale (length, 3.5 mm).

A globular cluster, M 53, used as a control, showed considerable deviations from an F9 star, which were attributed to the red and blue stars known to be present in the cluster. For each nebula, however, a star was found in which the energy distribution did not differ appreciably from that of the nebula. The results suggest that elliptical nebulae are either aggregations of many nearly identical stars (permissible range from early G to late K) or single bodies having properties which are unfamiliar to us at the present time.

#### SPECTROGRAPHIC ROTATION OF UNRESOLVED NEBULÆ

Further information on the structure of nebulae is contributed by Humason's investigations of spectrographic rotation in three unresolved nebulae of quite different types, NGC 3115 (E7), 4111 (SBp), 4594 (Sa). The laws of rotation evidently differ, but in each case the angular velocity appears to be correlated with the distribution of luminosity as indicated by isophotal contours derived by Hubble. Discussion of the problem is deferred until the present results for the faint, outer regions have been supplemented by further observations.

#### THE LUMINOSITY FUNCTION OF NEBULÆ

The photographic luminosity function of nebulae has been redetermined by Hubble as a preliminary step in the definitive analysis of nebular surveys. The function, derived from the frequency distribution of  $m_a - m_n$  (differences between apparent magnitudes of nebulae and of their brightest stars), from residuals in the velocity-distance relation and from the dispersion of apparent magnitudes within the great clusters, approximates a normal error-curve in which  $M_o = -14.2$  and  $\sigma = 0.83$ .

Other results of the investigations are:

(a) Total luminosities of regular nebulae of all types, whether in clusters or in the general field, are closely comparable, but the rare irregular nebulae average half as bright as the regulars.

(b) Luminosities of the brightest stars increase systematically along the sequence of nebular types; in late-type spirals and irregulars,  $M_o = -6.1$  and  $\sigma = 0.4$ .

(c) The several brightest nebulae in the great clusters have been calibrated as criteria of distance; e.g., the average luminosity of the fifth nebula is  $M = -16.45$ .

(d) The dispersion in the peculiar radial velocities of field nebulae is about 200 km/sec.

(e) The coefficient in the velocity-distance relation, revised for effects of selection, is about 528 km/sec per million parsecs.

#### INTERPRETATION OF RED SHIFTS

Another preliminary step in the analysis of nebular surveys was a joint investigation by Hubble and Prof. R. C. Tolman, of the California Institute of Technology, in which theoretically possible methods of studying the nature of red shifts were adapted to the conditions imposed by actual observations.

Both apparent luminosities and luminosity gradients in nebulae are affected by red shifts, which differ in amount according as the red shifts are velocity shifts or not. The study of luminosity gradients is not yet practicable, but the effect on apparent luminosities can be derived from the nebular surveys on the apparently well-founded assumption of uniform distribution. Provisional analysis suggests that the data might be accounted for on either interpretation of the red shifts. However, if red shifts are true velocity shifts (an expanding universe), a positive spatial curvature must be introduced whose radius is not greater than the range of the 100-inch reflector.

#### RED SHIFT WITH A GRATING SPECTROGRAPH

Adams and Humason have obtained a grating spectrogram of the spiral NGC 4151 (whose stellar nucleus gives an emission spectrum). The measured red shift for  $N_1$  and  $N_2$  is +962 km/sec. The agreement of this result with the value +958 km/sec previously derived from prism spectrograms shows that the relation between the fundamental constants  $h$  and  $c$  (Planck's constant and the velocity of light) is essentially the same in light from distant nebulae as in that from laboratory sources. The constancy of  $c$  had previously been established within a very small probable error by Strömberg's measures of aberration for light from the cluster of nebulae Ursa Major No. 1. The new observation therefore establishes the constancy of  $h$  within the same limit of uncertainty.

#### A SUPERNOVA IN THE VIRGO CLUSTER

Systematic observations of the Virgo Cluster were initiated at Mount Wilson in 1928 for the purpose of determining the frequency of supernovae in extragalactic nebulae. The first result of the search was a supernova found by Hubble and Moore in January 1936 in the spiral NGC 4273. Baade established a sequence of comparison stars near the spiral and has derived the light-curve of the nova from plates by various observers. The maximum was of the order of  $M = -12.4$ , and the star faded nearly 3 mag. in 100 days.

Spectrograms by Humason, presumably 5 and 6 weeks after maximum, were interpreted as showing wide, partially overlapping emission bands centered near  $H\beta$ ,  $H\gamma$ ,  $H\delta$  (probably compound),  $\lambda 3787$  and  $\lambda 4640$ , the last being the most conspicuous. Velocities of the order of 6000 km/sec were estimated on the assumption of an expanding shell. Humason also measured the red shift in the nucleus of NGC 4273 (vel = 2200 km/sec) for the purpose of correcting the measures in the spectrum of the nova.

About 100 days after maximum, when the star was faint (pg.  $m = 17.4$ ), Baade obtained a spectrogram showing a single band, 203 Å wide, within the range  $\lambda 3900$  to  $\lambda 5000$ . The center of the band, corrected for red shift, was at  $\lambda 4641$ , which suggests that it represents the well-known  $N^{++}$  line. This spectrogram fully confirmed the interpretation of the early spectra as overlapping bands.

The ultraviolet spectrum was observed by Smith about 6 weeks after maximum with a quartz spectrograph and f/1 Schmidt camera. The exposure time was 8 hours. A remarkable feature of the spectrum is the very

rapid fall of intensity toward shorter wave-lengths. It disappears completely at  $\lambda 3400$  although the sky spectrum, which appears on the same plate and is much less strong than that of the nova in the visible region, extends far below this limit. It is probable that all the light is due to emission bands. A band at about  $\lambda 3750$  (uncorrected for the red shift of the nebula) is fairly distinct and another is probably present near  $\lambda 3500$ .

## LABORATORY INVESTIGATIONS

### RARE-EARTH SPECTRA

In the course of the study of the europium spectrum being carried on in collaboration with Russell, King has photographed and measured a large number of the fainter lines which were needed to complete the multiplets for certain levels and has classified these as due to neutral or ionized europium. A supply of europium donated by Dr. Herbert N. McCoy of Los Angeles has made this additional work possible. On the later spectrograms lines are especially numerous in the region of shorter wave-length, as is illustrated by the fact that the list previously published for the range  $\lambda 3900$  to  $\lambda 4700$  has been increased by more than 500 lines. The final work of temperature classification is being completed.

In analyzing the arc spectrum of europium, Russell has found the low  $^1D$  and  $^3D$  terms arising from the configuration  $(4f)^6 6s 5d$ . Combinations of these with PDF triads account for almost all the strong lines in the yellow and red. Further investigation is deferred until the completion of the additional measures by King.

Dr. Albertson has analyzed the spectrum of singly ionized samarium (62), accounting for the origin of nearly all the observed radiation. The analysis includes the classification of more than 1200 emission lines from King's furnace data and involves 230 energy levels. The density of energy levels in  $Sa II$  is the highest observed thus far for any atom. The normal electron configuration for  $Sa II$  proves to be  $f^6s$ , which gives rise to the two ground multiplets,  $^6F$  and  $^8F$ . The levels from the configuration  $f^6d$  are found at about 1 volt energy above  $^6F$  and  $^8F$ . The assignment of quantum numbers to the energy levels and the analysis in general have been checked by measurements of the  $\pi$ -components of the Zeeman patterns of nearly 300 of the strongest lines. These measurements, made by Albertson and King, are in the regions  $\lambda \lambda 3560-4750$  and  $\lambda \lambda 6180-6900$ . The exposures were taken with the source placed between the poles of the large Weiss magnet, excited to 31,100 gauss. Similar material for the Zeeman effect has also been obtained by Albertson and King for the spark spectra of cerium (58) and gadolinium (64). These data will be an important aid to the analysis of  $Ce II$  and  $Gd II$ . A start on  $Gd II$  has been made by Albertson and is being extended with the aid of wave-lengths and other material for the furnace emission spectrum supplied by King.

Russell has completed and published new tables of the theoretical intensities of lines in multiplets, extending to the high multiplicities and term-types recently discovered in the spectra of the rare earths.

## PHOTOGRAPHIC PHOTOMETRY OF IRON ABSORPTION LINES

R. B. King and A. S. King have continued the measurement of the relative  $f$ -values of lines of  $Fe\ I$  in absorption spectra of the electric furnace by the method described in last year's Report. This work involves the measurement of the total absorptions of lines of favorable strength. When corrected for the Boltzmann distribution in the furnace, the absorption is directly proportional to the number of atoms in the line of sight *times* the  $f$ -value for the line. During the year,  $f$ -values have been obtained for 87 lines in 11 multiplets between  $\lambda 2900$  and  $\lambda 3650$ , and for 31 lines in 6 multiplets between  $\lambda 4300$  and  $\lambda 5500$ . Results are now available for a total of 193 lines in 26 multiplets from  $\lambda 2900$  to  $\lambda 5500$ . These multiplets arise from the low levels  $a^5D$ ,  $a^6F$  and  $a^3F$ , of excitation potentials 0.0, 1.0 and 1.5 volts, respectively, and include all but the weakest from these levels within the region investigated. The work is now being extended to the spectrum of neutral titanium.

## PHOTOMETRIC INTENSITIES OF EMISSION LINES

A method has been developed by Minkowski and King by which the structure of iron lines in furnace emission spectra is better adapted for accurate photometric treatment. The intensity measures of such lines are as a rule affected by self-reversal due to absorption by cooler vapor near the end of the furnace tube. A slow stream of nitrogen, which enters the tube at the end toward the spectrograph and keeps the iron vapor confined to the portion of the tube at uniform temperature, makes it possible to eliminate self-reversal. Preliminary results for intensities of iron lines produced by this method are in general agreement with the values found by R. B. and A. S. King for intensities in absorption.

## THE SPECTRA OF METEORITES

A spectroscopic analysis of 13 meteorites, based on over 60 spectrograms for the range  $\lambda 2500$  to  $\lambda 6750$ , has been carried out by King. The purpose was to study the effectiveness of this method, seldom used for meteorites, and to show how it may supplement the chemical and mineralogical analyses. Arc spectra were used for the most part, and rapid identification of most of the meteoritic lines was made by photographing arc spectra of the more prominent elements on the same plate. The types of meteorites examined included the nickel-iron and stony varieties and a carbon nodule. Thirty-two elements were identified, some of them, as nearly as could be judged by comparing the available chemical analyses, being present in amounts not greater than a few parts in a million. The iron meteorites, composed largely of iron and nickel, were found to contain in small amounts nearly all the elements identified. Their content of chromium and manganese was notably low as compared with terrestrial irons. Stony meteorites contain much less iron and very little nickel, but are rich in magnesium, sodium, silicon and chromium. In both types, especially in the iron meteorites, lines of the rare elements gallium and germanium appeared. These are found in very small quantities in some igneous rocks, and their lines, together with those of the rare element scandium, found in the stony meteorites, are observed in celestial spectra. Lithium, whose presence in meteorites has been uncertain, showed a clear

spectrum. As compared with calcium, the proportion of the related elements strontium and barium was found to be very small. Estimates of the relative abundance of meteoritic elements, based on the number and spectral type of the lines which appeared, showed that elements present in considerable amounts are confined to the first third of the atomic-number series. The most promising extension of this work appears to be in quantitative spectroscopic analysis, which is more rapid and often more sensitive than the chemical and mineralogical methods, and should be used in conjunction with these methods.

Other short spectroscopic studies by King included additional spectrograms of the red cyanogen band system obtained in connection with the work of Sanford and Merrill on red stars, absorption spectra of titanium and vanadium, emission furnace spectra of thorium for the selection of low-level lines in this very rich spectrum, and the determination of the minimum temperature for the appearance in absorption of zero-level iron lines as slightly below  $1200^{\circ}\text{C}$ . This temperature, much below the melting point ( $1530^{\circ}$ ) of pure iron, is sufficient when iron is vaporized in the presence of carbon.

#### VACUUM SPARK

Anderson has devoted some time to the problem of developing the vacuum spark into a useful laboratory source, the object in view being to employ it instead of the spark in air for general spectroscopic work. It would have two great advantages: the complete suppression of the troublesome air lines and the extent to which it would favor the higher stages of ionization. The preliminary work, in which two very different vacuum chambers were used, revealed several difficulties which must be overcome before a really satisfactory design can be made, but there is no reason to believe that these are very serious.

#### ELECTRICALLY EXPLODED WIRES

Recently Smith and Anderson have joined in a study of electrically exploded wires in vacuum and in low-pressure gases, of which nitrogen, hydrogen, carbon dioxide, and helium have so far been tried. The chamber in which the explosions take place was designed by Smith and constructed under his direction in the instrument shop. It contains a mechanism for "reloading" the wires which works perfectly even in the highest vacuum, and permits the explosion of as many as a hundred wires without opening the chamber or disturbing the vacuum. The results so far obtained at pressures up to a few centimeters of mercury exhibit a great variation, not only with pressure, but also with the kind of gas surrounding the wire. It is becoming more and more evident that the phenomenon called "electrically exploded wires" is, in reality, very complicated, and the present study should lead to a better understanding of its real nature.

#### INSTRUMENT DESIGN

A very fast Schmidt camera has been designed by Smith which corresponds in principle to an oil-immersion objective. In place of the usual spherical mirror a block of glass is substituted which has one plane surface and one spherical surface. The photographic plate is carried in contact with a



liquid on the plane surface and the spherical surface (silvered) occupies its usual position. The advantages of such a camera consist in great speed without undue sacrifice of field and almost complete freedom from change of focus with temperature.

A machine of improved type for giving directly values of the reduction to the sun in observations of stellar radial velocities has been designed by Christie to replace the instrument, also of his design, which has been in regular use for several years. It will be wholly mechanical in operation and should give values accurate to nearly one hundredth of a kilometer. The mechanism is such that it may also be used for the transformation of co-ordinates and the solution of certain spherical triangles.

Christie has also designed a simplified form of schraffierkassette which greatly reduces the cost of such an instrument.

#### RULING MACHINES

The most important work completed during the year by Babcock and Prall has been the construction of a revised diamond carriage for the new machine. This embodies in a modified form the elements of the design that was adopted by Rowland and shown by him to be adequate, but has certain advantages such as reduced weight, greater rigidity, diminished sensitivity to temperature changes, and a notable minification of errors that are transferred from the ways to the diamond. Since its completion last spring the carriage has been operated sufficiently to complete the polishing of its bearing surfaces and to show its marked advantages over the original carriage.

The large spacing gear of the new machine has been corrected by a special method of grinding, and the most important errors have been removed. A decision as to the need of further refinement awaits the results of more ruling tests, but in general errors of a periodic or systematic character seem to be sufficiently low in amplitude, and the remaining difficulties are of the accidental type. Rulings sufficiently good for many purposes can now be produced on this machine.

The old ruling machine has been used at intervals throughout the year. Its spacing gear requires corrections similar to those applied to the new machine.

Recent rulings show only small errors, except for those of a periodic character, which are inherent in the gear. This machine will be thoroughly overhauled as soon as the needs of the new machine permit.

The process of cutting and polishing the ruling diamonds has been made shorter and more certain through the successful use of cutting laps of high grade cast iron; and the successful casting of a number of excellent 4-inch speculum plates in a small gas furnace has afforded opportunity for studies of composition, methods of reducing oxidation and the technique of casting and annealing.

Several small gratings have been ruled on thin films of metal deposited on glass by Dr. Strong, of the California Institute of Technology. He has been able to make these thick enough to receive rulings of full depth at ordinary spacing (15,000 per inch). Although some new difficulties attend this technique, it seems to offer a means of obtaining increased brightness in the spectrum as compared to speculum. Further experiments are in progress.

## CONSTRUCTION AND MAINTENANCE

### A NEW AUDITORIUM AND EXHIBITS BUILDING

The completion of the new highway to Mount Wilson and the growing interest of the public in the results of astronomical study and in astronomical instruments have led to a very great increase in the number of transient visitors to the Observatory. During the past year more than 50,000 persons have seen demonstrations of the 100-inch telescope, and 14,500 have made visual observations with the 60-inch telescope on Friday evenings. Among these have been several thousand students from the schools and colleges of Southern California.

With a view to presenting more directly and effectively to the public some of the results of the work of the Observatory and the Carnegie Institution the Trustees of the Institution, on the recommendation of the President, made an appropriation for the construction of a new building to include a lecture room and a room for astronomical exhibits. It will replace the small wooden building which has housed the exhibits for many years.

Construction work on the building under the supervision of A. N. Beebe was commenced in May and should be completed during the autumn. It will be of reinforced concrete and gunite construction with an insulated steel roof and insulated walls. The lecture room 60 x 40 feet in size will provide about 300 seats and the exhibit room 28 x 40 feet has adequate wall space for 42 transparencies. Astronomical lectures will be given in this building on Friday evenings, when the public is admitted to the 60-inch telescope building for observations, and the exhibit will be open for use each day.

### THE 100-INCH TELESCOPE

At the time the 100-inch telescope was under construction in 1917 the difficulty of obtaining mercury for the flotation system was so great that the clearance between the mercury tanks and the cylindrical drums was made as small as possible. The tanks were lined with thin sheet steel fastened to the cast-iron walls and the end thrust was adjusted to center the drums accurately within the tanks. In general the operation of the telescope throughout the years was excellent, but occasionally indications of friction appeared on the surface of the rotating drums. Evidently these were due to the gradual accumulation of oxide and dust on the surface of the mercury which formed small hard masses in the narrow space between the walls of the tank and the drum. It is also probable that earthquake shocks had impaired the clearance slightly.

Last autumn the driving of the telescope became more irregular and it was decided to overhaul the flotation system thoroughly. The mirror and cell were removed, the main yoke was blocked up and the mercury tanks were drained. The tanks were then opened and the drums raised sufficiently to allow removal of the steel linings. This necessitated unbolting the south portion of the polar axis from the main yoke. The mercury was cleaned and replaced and additional mercury was added to provide for the additional clearance gained through removal of the linings. The balls in the end-thrust

bearing were also renewed. The work required about 6 weeks and was carried out by the regular members of the Observatory force.

Since this work was completed the driving of the telescope has been very satisfactory and much less affected by changes of temperature than during recent years.

#### GENERAL CONSTRUCTION

A new exit stairway has been completed in the 100-inch telescope building which greatly facilitates dealing with the large numbers of visitors during the hours when the instrument is demonstrated. Another important improvement in this building was the completion during the winter of the electrical welding of the rails upon which the dome turns. This work, together with general repairs and maintenance, has been under the charge of A. N. Beebe, superintendent of construction. Sidney Jones, engineer on Mount Wilson, and Kenneth de Huff, assistant engineer, have cared for the mechanical and electrical operation of the instruments and are installing the electrical wiring in the new auditorium.

In the instrument shop, under the direction of Alden F. Ayers, the following instruments and apparatus have been constructed; the Fabry-Perot interferometer spectrograph; a new 20-inch telescope mounting; a double-slide plateholder and frame for the 100-inch telescope; the diamond carriage and other parts for the ruling machines; several Schmidt cameras; and additions to the large coude spectrographs. The design of these instruments has been due to E. C. Nichols, in charge of the engineering department, assisted by H. S. Kinney. The detailed design of the new auditorium has also been carried out in this department.

John S. Dalton, optician, and D. O. Hendrix, assistant optician, have been engaged in a wide variety of optical work. This has included the lenses, prisms and Schmidt camera for the interferometer spectrograph; the plates and concave mirrors for several other Schmidt cameras; a 30° crystalline quartz prism over 4 inches in diameter; and many smaller lenses, mirrors and prisms of glass, pyrex and quartz. The curves upon the lenses for the zero corrector of the 100-inch telescope have been modified in accordance with the calculations of Dr. Ross. Many speculum plates have been figured for the use of the ruling machines.

#### THE LIBRARY

During the past year the library has added 329 volumes, 54 by gift, 78 by purchase, and 197 by binding; the total number is now 13,144, with over 10,000 pamphlets. In 1936 the library is receiving regularly 134 serial publications; of these, 39 are gifts or exchanges, as are also the publications of more than 200 observatories and research institutions.

## DIVISION OF PLANT BIOLOGY <sup>1</sup>

H. A. SPOEHR, CHAIRMAN

Within recent years there have been some indications that agriculture may be entering upon a period of fundamental changes in practise, which may prove to be quite as drastic and far reaching as occurred in manufacture and transportation as the result of the industrial revolution of a century ago. The real issues in this great readjustment have not yet been clarified and are in no small measure obscured and confused by the traditional reluctance of agriculture to give way to a new order, because of the complex of social, economic and political traditions which are involved. But to a large extent economic and political expressions are but symptoms of more fundamental forces. Economic fluctuations in regard to agriculture are not unrelated to the great complex of relationships between weather, soil and the growth of plants. The living plant and all of its products represent a dynamic, reciprocal relationship between the functioning of the organism and its environment. The reaction of plant to environment is not haphazard; complex though it be, it reveals on careful study, certain dominant regularities. So also climate and the whole environmental complex are objective phenomena, which lend themselves to patient, orderly scientific research.

There can be little doubt but that one element in any rational readjustment of methods of agriculture must be the knowledge of the functioning of plants and of their relation to their environment. As a matter of fact, this scientific element has received less popular attention in a consideration of the problem than other more conspicuous, though less fundamental, aspects. Out of the patient accumulation of scientific information concerning plants are emerging new methods of growing crops and new uses of the products, which are not only important as foodstuffs, but which are potentially of great significance to industry. It is in the very nature of scientific development that its first steps are cautious and unobtrusive, that it does not impress itself upon the unimaginative public mind, preoccupied with immediate economic and political subjects. But the consequences of such scientific development are none the less potent and appear surprising to unprepared minds. The importance of such developments can hardly be overemphasized, and it is quite conceivable that they will be directly determinative in case any readjustment of agriculture is to follow. Certain it is that in the great balancing of forces which determine a movement of this magnitude, scientific facts concerning the central element involved, namely the living plant, will play a rôle as decisive as the economic and social factors which are dependent upon it.

What contributions to this problem can be made by an agency such as the Carnegie Institution is too large a question to be discussed in the compass of this report. But a careful study of the many types of institutions and organizations whose combined efforts are providing an ever increasing body of essential information on this subject has led to the formulation of certain ideas and policies which have been applied within the Division of Plant

<sup>1</sup> The Central Laboratory of this Division is located at Stanford University, California.

Biology. Since the inception of the Institution the policy "to encourage in the broadest and most liberal manner investigation, research and discovery, and the application of knowledge to the improvement of mankind" has made possible the intensive investigation of certain fundamental problems over extended periods of time. It has thus been possible to concentrate effort on relatively few projects which seemed to be of basic importance, and to pursue these intensively, unhampered by pressure for immediate results or applications. As a matter of experience, the applications of the discovery of fundamental facts follow relatively rapidly and almost automatically, there being many agencies and facilities, with vast financial support, organized to try out on a large scale and put into practise any new idea.

The investigations which are being pursued by the various sections composing the Division of Plant Biology are in principle of two sorts. There are investigations representing intensive and specialized study of individual functions and components of plants. Such investigations are designed to analyze particular activities, the agents or forces which produce these and the factors which influence them. These efforts concern themselves primarily with the chemistry of the materials of which the plant is composed and the chemical changes involved in some of the more important activities characteristic of plant life. Another group of investigations concerns itself with attempts to synthesize the various elements which enter into the life of all vegetation or of plant aggregations and societies. They constitute attempts to determine the interrelationship and interplay of forces which result in the vegetation on the earth today and the development of concepts as to the manner in which it has changed during geological periods. These investigations deal primarily with the interplay of forces within the organism and of the environment to which it is exposed. These two lines of investigation, in a sense, represent opposite approaches to the same or closely allied problems, the one specialized and analytical, the other reciprocal and synthetic. Both have yielded results bearing directly on fundamental processes occurring within all plants, on environmental influences affecting form and function, and on the rhythms and periodicities which are an expression of the interplay of these forces.

During the past half century the phenomenon of photosynthesis has been investigated primarily through intensive studies of the rates of the reaction under various environmental conditions. While these studies have aided materially in elucidating many aspects of the problem, they have also demonstrated the importance of a clearer understanding and of more exact information concerning the reactants which play a rôle in the process and of the nature of the system in which the photosynthetic reaction occurs. It seems clear that the formulation of hypotheses to guide experimental study of the process is in no small measure restricted by our limited knowledge of the photosynthetic apparatus of the living leaf. Biochemical investigations can contribute materially toward a better understanding of the materials and physical factors of this apparatus, and the investigations carried out in this Division have for some time had this as their main objective. These

have been concerned chiefly with intensive studies (1) of the carotenoid pigments, (2) of the primary reactant with carbon dioxide, and (3) of the conditions which affect enzyme action in chlorophyll-bearing cells. The more exact information on the carotenoid pigments and some of the colorless compounds related to them has made possible their sharper separation and more precise quantitative determination than heretofore, and has given a better understanding of the relationships of these substances, their properties, and possible rôle in the living cell. A compilation for publication of much of this work is now in progress. The investigations on the primary reactant with carbon dioxide, while still in the early stages, have demonstrated the significant fact that leaves contain a substance or complex capable of absorbing carbon dioxide in excess of the amount dissolved by the water, that this is a reversible reaction and is not associated with chlorophyll. The conditions affecting enzyme activity in leaves have been studied primarily by following the variations of the synthesis and decomposition of starch. The inhibition of these reactions under anaerobic conditions or of impaired aeration is apparently due to the accumulation of certain metabolic products which act directly or indirectly upon the enzyme system.

The joining of anatomical and chemical approaches to the problem has made possible the development of very useful methods for the isolation and analysis of important constituents of wood. This concatenated effort is yielding encouraging results for a better understanding of the chemical and physiological processes involved in the laying down of the materials of wood and the secondary changes occurring in it.

Elucidation of the species problem has been a foremost objective of the work in experimental taxonomy. It is becoming evident that plant species have a definite genetic basis as well as hereditary boundaries which mark their limits. In a number of examples these boundaries have been explored and defined through garden experiments designed for the purpose. These results have demonstrated that species not only have a factual basis, but are capable of objective study. The genetic barriers that mark natural species are incompatibilities of various sorts. The results of extensive experimentation show that if species are able to hybridize at all, their hybrids are either partially or completely sterile, or the second generation offspring show so marked a decline in vigor that they will be eliminated under natural conditions. Subspecies, on the other hand, are interfertile, but are characterized by geographic or ecologic preferences, resulting from natural selection of suitable characters for particular environments, that tend to maintain their identities. These conclusions have largely been drawn from garden studies of the *Madinæ*, but investigations on transplants and West American species of *Viola* and *Penstemon* have also contributed to the results.

Work at the Desert Laboratory has centered in a continuation of the investigation of the Sonoran Desert, which has been under way for the last three years, as well as in the study of certain features of physical conditions and plant behavior which are intimately concerned with it. Field work was conducted in extreme northwestern Sonora and in western Arizona under seasonal conditions which emphasized the difficult environment that is found in the most arid part of the Sonoran Desert. The volcanic area surrounding

Pinacate Peak was visited and the adjacent sandy plains and dunes which constitute a unique part of the American desert, resembling the Sahara and the Arabian desert. A series of plants from the remoter parts of the Sonoran Desert has been brought into cultivation for study, as little is known about them except their genetic relationship. Five small areas in the grounds of the laboratory on which the location of every perennial plant was mapped 30 years ago have been remapped, showing increases in the plant population and changes in the relative numbers of the different species since the areas were last examined, eight years ago. In some cases there has been a greater increase in the number of plants in the last eight years than in the first 22 years of the period in which the grounds have been protected from grazing animals. The investigation of rainfall, soil moisture and soil temperature continues to receive the attention that these features command because of their importance in controlling the activity and distribution of desert plants.

The paleobotanical investigations of the past and present distribution of forests give indication of a southward movement in later geological time. The vegetation of California during the Eocene period (dawn of the recent) resembles that on the lower slopes of the Plateau of Mexico today. The forests of Alaska of this early period have moved down to occupy the Redwood Belt of California and to extend southward along the mountains into Mexico. A major cause of forest migration appears to be a trend toward cooler and dryer climate. This may in turn be due to the gradual emergence of the western part of the North American continent and the upbuilding of its mountain ranges during later periods of earth history.

Climatological researches during the past year have been extended, first in fundamental studies of uniformity of tree ring records from different sources; second, in improvement of quality of ring records used in the long chronologies; third, in publication of a volume on cycles, completion of other shorter manuscripts and the strong beginning of a photographic chronology. The staff and cooperative work with the University of Arizona continue as stated in the last Year Book.

## BIOCHEMICAL INVESTIGATIONS

By H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN AND H. W. MILNER

### CAROTENOID PIGMENTS

As a result of the improvement of methods for the isolation and separation of carotenoids it has been found that leaves contain twelve or more xanthophylls. The isolation of the xanthophylls in condition suitable for adsorption was accomplished by removal of the chlorophyll from methanol extracts of leaves by saponification. The xanthophylls were transferred to ether and crystallized by the addition of petroleum ether. The crystalline xanthophyll mixture thus obtained was dissolved in dichloroethane and separated by absorption upon columns composed of magnesium oxide. Under these conditions many of the xanthophylls were recovered in sufficient quantity to permit the determination of their physical properties and their approximate chemical composition. The proposed names, the empirical for-

mulas assuming that each pigment contains 40 carbon atoms, the optical rotations and the wave-lengths of the absorption maxima of each of the principal constituents of the crystalline leaf xanthophyll are recorded in the following table. The xanthophylls are listed in the same order in which they occurred on the adsorption column.

Name	Formula	Absorption maxima in ethanol	Optical rotation in $\text{CHCl}_3$	Yield from 1000 mgm. Xanthophyll
		$m\mu.$	$[\alpha]_{6678}^{18}$	$mgm.$
Neoxanthin.....	$\text{C}_{40}\text{H}_{56}\text{O}_4$	437 466	+32	80
Flavoxanthin c.....	$\text{C}_{40}\text{H}_{56}\text{O}_3$ or $\text{O}_4$	424 450	-56	22
Flavoxanthin b.....	$\text{C}_{40}\text{H}_{56}\text{O}_3$ or $\text{O}_4$	424 450	+75	19
Violaxanthin b.....	$\text{C}_{40}\text{H}_{56}\text{O}_4$	442 471	+33	26
Zeaxanthin.....	$\text{C}_{40}\text{H}_{56}\text{O}_2$	452 480	-41	8
Isolutein.....	$\text{C}_{40}\text{H}_{56}\text{O}_4^*$	446 473	0	5
Lutein.....	$\text{C}_{40}\text{H}_{56}\text{O}_2$	447 475	-151	250

\* The behavior of the isolatein upon the adsorption column indicated the presence of methoxyl groups, but the quantity of pigment did not suffice for the determination of these groups.

Very small quantities of several xanthophylls were adsorbed at the top of the column above the neoxanthin and small quantities of weakly adsorbed pigments were observed below the lutein band. These weakly adsorbed xanthophylls were separated into four pigments. Two of these resembled cryptoxanthin and two resembled carotene with respect to their distribution between immiscible solvents. All four exhibited absorption maxima similar to those of beta-carotene and cryptoxanthin. The pigment adsorbed second below the lutein band could not be separated from cryptoxanthin when mixed with the latter and adsorbed upon a fresh column of magnesia. These two pigments must therefore be very similar or identical.

The green leaves of twenty-five different species of plants, distributed in nearly as many botanical families, were examined by the adsorption method and found to contain the same xanthophylls in approximately the same proportions. The yellow fall leaves of several plants appeared to have lost much of the xanthophyll with the exception of zeaxanthin. The yellow portions of variegated leaves resembled fall leaves with respect to the composition of the xanthophyll. Etiolated barley seedlings contained large quantities of xanthophylls and these were in proportions similar to those found in green leaves.

The adsorption method can be made one of the most sensitive and specific for the separation and identification of the carotenoid pigments. By the use of micro-adsorption columns, 0.5 to 1.0 mm. in diameter, composed of magnesia and siliceous earth, as little as 0.0015 mgm. of carotene was easily separated into alpha- and beta-carotene. By adsorption of the carotenoids from single needles of *Cedrus deodara* and *C. atlantica* and from single segments of carrot leaves the presence of alpha- and beta-carotene and



mixtures of xanthophylls, similar to those obtained from other green leaves, could be demonstrated.

An examination by means of adsorption and spectral absorption methods of the crystalline xanthophyll mixtures isolated from leaves disclosed that the composition of the xanthophyll was altered in the process of crystallization. In order to obtain an accurate absorption spectrum of the mixture of xanthophylls which occurs in leaves, leaf xanthophyll was separated from chlorophyll by saponification and from carotene by partition between menthanol and petroleum ether. The characteristic absorption curve of the xanthophyll solution was determined. This curve was very similar to that of lutein, the principal constituent of leaf xanthophyll, but the absorption maxima were about 4  $\mu$  nearer the violet portion of the spectrum. These observations revealed that neither pure lutein nor crystalline xanthophyll mixtures can be used as standard or reference substances for the precise determination of the xanthophyll content of green leaves by comparative spectral absorption or colorimetric methods.

The great reactivity of the xanthophylls has led to the suggestion that some of the xanthophylls observed in leaves may have been the result of *post mortem* reactions or alteration products of a single leaf constituent. Carefully controlled experiments have demonstrated that the xanthophylls isolated from leaves by adsorption are not the result of *post mortem* reactions. Neither are the xanthophylls formed by the action of the alkali during saponification, by the action of oxygen during isolation, nor by reaction with the adsorbent.

Zeaxanthin, contrary to recent reports, was found to be optically active. Lutein was found to melt at two temperatures, depending upon the method employed in its crystallization. A study of the properties of mixtures of lutein and zeaxanthin demonstrated that, on the basis of melting points and wave-lengths of maximum absorption, mixtures of these two pigments, containing as little as 30 per cent of lutein, might be construed to be pure lutein. Many of the xanthophylls retain solvent of crystallization which is removed with difficulty. The retention of solvent appeared to depend upon the presence of the hydroxyl groups, because carotene and xanthophyll esters did not exhibit this property. All xanthophylls, when dissolved, were rapidly altered by heat. Similar alterations occur when adsorbed pigments are heated. The spectral absorption coefficients of most of the xanthophylls were determined in several different solvents. The coefficients of absorption of lutein and zeaxanthin in solution in ethanol and in chloroform were greater than those reported by other workers, but the coefficients of solutions in carbon disulfide were less. A comprehensive report on the isolation and properties of the leaf xanthophylls is now being prepared for publication.

It has long been suspected that the carotenoid pigments in leaves might undergo rapid chemical changes, but such reactions have never been demonstrated. It has now been found that the carotenoid pigments are rapidly decolorized when leaves are frozen and thawed or ground with sand. This reaction is more rapid in young leaves than in older ones and is extremely rapid in etiolated seedlings, more than 90 per cent of the pigment disappearing after 5 minutes of grinding. The decolorization of the pigments does not take

place in the absence of oxygen or in the presence of dilute solutions of acids, alkalis, and copper sulfate. Grinding the leaves in 30 per cent acetone retards the oxidation slightly, but grinding in pure acetone almost stops the reaction. Heating the leaves before grinding prevents the oxidation. Sufficient information has not yet been obtained to determine whether the oxidation of the yellow pigments is dependent upon the action of an enzyme or upon the state of the pigments in the leaf or whether both of these factors are of significance.

The oxidation of the yellow pigments during grinding is of great significance in relation to methods for the determination of the carotenoids. Grinding of leaves with sand or with sand and 30 per cent acetone is the first step in the methods most commonly used for the determination of the carotenoids. The losses of the yellow pigments at this step, which may amount to 50 to 60 per cent of the total carotenoid content, may be sufficient to vitiate the experimental results.

Examination of leaf extracts by means of adsorption columns demonstrated the presence of a number of colorless substances. Some of these were not adsorbed and showed very low absorption of ultra-violet light, which indicated that they were saturated hydrocarbons. Others were weakly adsorbed and these exhibited complex absorption of ultra-violet light. The spectral absorption measurements in the ultra-violet were made in cyclohexane solution by Dr. W. G. Leighton in the region 2400 to 4000 Å, with the apparatus he has been developing in this laboratory. Of particular interest were two substances which were strongly fluorescent in ultra-violet light. These leaf constituents formed fluorescent bands or zones upon the adsorption columns below the alpha-carotene band. Crystals isolated from the fluorescent bands were also fluorescent, being comparable to anthracene and carbazole in this respect. The fluorescent light ranged from the green to the red wave-lengths. The behavior of the fluorescent materials upon the adsorption columns indicated that neither substance contained ester, carboxyl or hydroxyl groups or their analogs. One or both of the fluorescent substances have been isolated from many plant products, from etiolated seedlings and from all the green leaves which have been examined. Small quantities of other fluorescent substances have been observed to form fluorescent bands above the beta-carotene upon the adsorption columns. These reactive materials, by their fluorescence and concomitant activation may affect many physiological processes such as photosynthesis, pigment formation, cell elongation, and light tropisms, and may account for some of the fluorescence of etiolated seedlings and of other pigment-free parts of plants. Since there is some evidence that carotenoids may be formed in plant products by dehydrogenation reactions, the weakly adsorbed, colorless constituents of leaves may be regarded as possible precursors of the yellow pigments.

#### THE ABSORPTION OF CARBON DIOXIDE BY THE UNILLUMINATED LEAF

It has been realized for a long time that the absorption of carbon dioxide from the surrounding medium by the chlorophyll-bearing tissue constitutes the first step in the photosynthetic process and that there must exist some mechanism or substance by means of which this is accomplished. The con-

centration of carbon dioxide in the air is very small; it is remarkable that the leaf can absorb and assimilate so rapidly such relatively large amounts of this gas. None of the hypotheses thus far proposed to account for this phase of the phenomenon of photosynthesis have proven satisfactory, and it has long been apparent that this feature of the photosynthetic apparatus is but poorly understood. An investigation of the carbon dioxide absorbing capacity of unilluminated leaves was undertaken in this laboratory some years ago (Year Book, Vols. 22-25), and during the past year this investigation has been resumed by the use of different methods.

From an extensive series of experiments it is apparent that within a leaf carbon dioxide exists in various degrees of fixity. That is, the carbon dioxide contained in a leaf may be separated into various fractions according to the ease with which it can be removed by different means. There is thus some indication that within the leaf there may be present compounds which may act as carbon dioxide reservoirs from which the carbon dioxide may be released with varying degrees of facility. How much of this carbon dioxide is actually available for the photosynthetic process is, of course, uncertain, and this can probably be determined only on the basis of more exact knowledge of the nature of the combinations in which the carbon dioxide exists. But it is clearly evident that the amount of carbon dioxide in the free state or in solution, as liberated by means of thorough evacuation, is less than that freed by means of boiling water, and that this amount, in turn, is less than the total freed by boiling with 12 per cent hydrochloric acid. The easily freed carbon dioxide is contained largely in the cell sap, whereas that obtained by treatment with acid apparently arises from the insoluble material of the leaf, probably in part at least, from the complex uronides of the structural elements of the leaf.

The absorption of carbon dioxide by some substance contained in the leaf can have biological significance for the interchange of this gas between the atmosphere and the chloroplast primarily if some form of reversible reaction is involved. For this reason this investigation has been directed toward the establishment of possible equilibrium relations between leaves and mixtures of gases surrounding them. This has been done on the basis of the amounts of carbon dioxide absorbed by unilluminated leaves as determined by evacuation methods.

From an extensive series of experiments with a variety of leaf material it is clearly evident that leaves absorb carbon dioxide reversibly. Moreover, the amount of carbon dioxide was always found to be in excess of the amount that the water, contained in the leaf, could have absorbed had it been in the free condition. The problem is, of course, intimately bound up with the question of the condition of the water as it exists in the plant. What is the nature of "bound water," and are there as yet unknown relationships of hydrol, dihydrol, trihydrol, etc., in the colloids of the protoplasm which affect these phenomena, are naturally questions which may have to be taken into consideration in this connection. But the solution of these problems depends upon highly specialized physical chemical research.

The experiments on the absorptive capacity of leaves show clearly that a large proportion of the carbon dioxide absorbed by the living leaf can be

ascribed to its water content. On the other hand, there is an excess of carbon dioxide absorbed over the amount which can be calculated as being taken up by the water. These relationships are, however, rather complex. By partially drying sunflower leaves the effect of varying water content was studied. The results indicate that the solubility of carbon dioxide in water of the leaf is greater than in pure water, for the decrease in absorption was found to be greater than corresponds to the loss of water. It has been found that the amount of carbon dioxide absorbed by leaves varies with the concentration of the carbon dioxide in the surrounding gas. At low concentrations the amount absorbed increases much more rapidly with increase in concentration than at higher concentrations. When the concentration of the carbon dioxide in the surrounding gas exceeds 30 per cent, the increase in absorption is almost directly proportional to the increase in concentration. Lowering the temperature increases the total absorption of carbon dioxide by the leaf. If, however, the amount of carbon dioxide absorbed by the water of the leaf is subtracted from the total absorption, the excess absorption appears to be nearly independent of temperature. Light has little, if any, influence on the absorption of carbon dioxide in the absence of oxygen.

The leaves of different species of plants exhibit considerable variation in their carbon dioxide absorbing capacity as measured in this manner. This capacity for absorbing carbon dioxide, while not entirely confined to leaves, is most marked in these organs. The colorless coleoptiles of barley seedlings absorb less carbon dioxide than the amount calculated for water present. Similarly, the roots of barley seedlings absorb only a small quantity in excess of the theoretical solubility in the water present. Petals of flowers show little or no absorption above that ascribable to the water present. Etiolated leaves absorb as much as green leaves and this increases with age, though as the dry weight also increases with age the absorptive capacity appears to decrease somewhat with age if calculated on a dry weight basis.

Carbon dioxide is absorbed from mixtures of this gas with air, nitrogen or hydrogen in the same way as from atmospheres of pure carbon dioxide. If the leaf is subjected to pure carbon dioxide at a series of pressures ranging from 70 mm. to 760 mm., the amount of carbon dioxide absorbed is approximately the same as when the carbon dioxide is present in other gases at the corresponding partial pressures.

There is no correlation between chlorophyll content and absorptive capacity. The colorless portions of variegated leaves absorb as much as the portions containing chlorophyll. Furthermore, no experimental substantiation could be found for the hypothesis that carbon dioxide combines with the chlorophyll as a first step in photosynthesis. Colloidally dispersed chlorophyll in water does in fact absorb more carbon dioxide than would be taken up by an equal amount of the water present in the colloidal solution. But when the chlorophyll, which is flocculated by the carbon dioxide, is removed from the mixture, it is found that the aqueous solution contains magnesium. Quantitatively the indications are that all of the excess carbon dioxide taken up by the chlorophyll solution could be accounted for as having combined with the magnesium which was split from the chlorophyll and dissolved in the water as a complex magnesium carbonate. Similarly,

glycerine extracts of leaves, which apparently contain the chlorophyll in a combined form, showed no absorption of carbon dioxide by the chlorophyll.

### AMYLOLYTIC ACTIVITY OF LEAVES

In the leaves of many plants there occurs during periods of illumination an accumulation of starch, which again disappears during periods of darkness or insufficient illumination. This process of dissolution of starch is brought about by the hydrolytic activity of the enzyme amylase, the presence of which can easily be demonstrated in starch-containing leaves. Amylase is a well-known enzyme, it has been isolated from many tissues of living organisms and its properties as well as the conditions influencing its activity *in vitro* have been intimately studied and are relatively well understood. On the basis of this knowledge it is rather surprising that the activity of the amylase within the cells of the leaf is so easily affected by agencies which are known to have no direct effect upon amylase itself. Thus it has been found that leaves which have been killed by means which are known to have little or no effect upon the leaf amylase, as for example by means of drying at low temperatures, freezing and various chemicals, are incapable of effecting a dissolution of their contained starch even under conditions most favorable to amylolytic activity. Chloroformed, toluenized, and frozen leaves, when kept sterile, show no visible decrease in their starch content even when incubated at 30° for months. When, however, such leaves are thoroughly ground, resulting in a breaking down of the cell structure and an intimate mixing of the cell contents, amylolysis proceeds, although with time its activity has been considerably reduced.

The fact that starch hydrolysis does not occur when the colloidal structure or phase relationships of the chloroplasts, which contain the starch, have been destroyed through freezing, drying, treatment with chloroform or toluene, in short, through the killing of the protoplasm, indicates that this function is dependent upon the finer structure of the cell. We have as yet insufficient knowledge of the structure of the chloroplasts, but it is becoming clear from experience gained through these investigations and from a study of chloroplast pigments that the nature of the colloidal state of the materials constituting the chloroplasts is of great significance in its functioning.

Even in the living state, leaves may exhibit considerable fluctuations in their amylolytic activity and this may apparently be brought about by various factors. It has long been maintained that amylolysis in living leaves can take place only in an atmosphere containing an adequate supply of oxygen, though it is known that the chemical reaction induced by the amylolytic enzyme does not involve oxygen. Similarly the synthesis of starch from simpler sugars by the living leaf has been supposed to be dependent upon the presence of oxygen. It is, in fact, true that when leaves are submerged under water or confined in an atmosphere of hydrogen or nitrogen, amylolysis is very slow or is completely inhibited. Even when leaves are confined in a relatively small volume of air, the rate of amylolysis is perceptibly reduced. When, however, living leaves are kept in an atmosphere of hydrogen or nitrogen in such a way

that a stream of the gas is passing over the leaves, starch depletion occurs. Under these conditions it has also been possible to effect a synthesis of starch from simpler sugars in leaves kept in an atmosphere free of oxygen. It would appear, therefore, that at least in the species which have been studied, oxygen is not essential for starch hydrolysis nor for starch synthesis.

What the causes are underlying the inhibition of amylolysis in leaves subjected to conditions of inadequate aeration or in confined atmospheres of hydrogen and nitrogen has as yet not been clearly established. This inhibition of the amylolytic process under anaerobic conditions or of impaired aeration is apparently associated with an accumulation of metabolic products which, directly or indirectly, affect amylolysis. It has been found that carbon dioxide inhibits amylolysis in leaves; the degree of inhibition, however, varies considerably with different species. For example, in sunflower and tobacco leaves the rate of starch depletion is decidedly less in an atmosphere of carbon dioxide than in air, while clover and bean leaves show no significant differences. No correlations have been found between the degree to which amylolysis is affected by carbon dioxide and the amount or activity of the amylase in different leaves; this varies greatly in different species. When leaves are exposed to carbon dioxide, notably in higher concentrations, a series of complex reactions is induced which may materially affect amylolysis. Of the changes thus produced by carbon dioxide, perhaps the most obvious are those of the acidity or hydrogen ion concentration of the cell sap. Amylase activity is markedly influenced by the hydrogen ion concentration of the medium and it is possible that carbon dioxide may exert its influence on the amylolytic activity through alterations brought about in the hydrogen ion concentration of the cell sap. The indications are, however, that the hydrogen ion concentration is not the only factor which controls the activity of the amylase and that the problem is considerably more complex.

In brief, it is apparent that when leaves are exposed to an atmosphere free of oxygen, a whole series of changes are brought about which materially influence even such relatively stable enzymes as the amylases. From the fact that lack of oxygen inhibits some of these enzymatic reactions it is, however, not justifiable to draw the conclusion that oxygen enters into these enzymatic reactions. It is rather that the leaf cells constitute a delicate apparatus, the normal functioning of which demands a supply of oxygen and in the absence of which chemical changes occur which produce products inhibitory or directly toxic to some enzymatic reactions. The exact nature of these inhibitory products and the reactions which produce them must still be more definitely determined. In all probability a very similar situation exists in relation to the apparent necessity of oxygen for the photosynthetic process. The photosynthetic apparatus is extremely delicate, and the exposure of a leaf or other chlorophyll-bearing organ to anaerobic conditions results in the formation of products (probably through anaerobic respiration or fermentation) which are deleterious to the functioning of the enzymes that play a rôle in photosynthesis.

Progress in an understanding of these problems depends in a large measure upon the development of reliable quantitative chemical methods which can

be applied to the plant materials under investigation. Besides the necessity of gaining reliable information on the hydrogen ion concentration of plant saps, it has been necessary to employ accurate methods for the determinations of starch in leaves which have been subjected to various treatments. A critical study of the existing methods demonstrated that these did not yield results of sufficient accuracy for the problems under consideration and that the most serious source of error was the presence in the leaves of dextrans in varying amounts and of different properties. The dextrans are very closely allied to starch, but there is a whole series of them which, in chemical and physical properties, differ sufficiently from starch to make it difficult to include them with starch in an analysis. It is also difficult to separate the dextrans from other allied substances present in leaves. It was therefore determined to make quantitative estimations of starch with the exclusion of the dextrans, and methods have been worked out which on critical test have yielded results with an accuracy of about 3 per cent. For the separation of the dextrans from starch, use has been made of the difference in solubility of the respective iodides in a solution of calcium chloride. While it is, of course, exceedingly difficult, if not impossible, to devise a method which is applicable to all plant material, the method under consideration has proven its reliability for a variety of plant material studied, and is being used in the investigations of the amylolytic activity of leaves under various conditions.

The method of starch determination just referred to has also been used to establish the nature of the starch separated from plant material by the freezing method, referred to in the Year Book (vol. 34, p. 199, 1935). It has been found that the starch isolated by freezing, while probably freer from contaminants than starch isolated by means of any precipitation method, includes varying amounts of dextrin. In fact, the starch obtained from a number of leaves, when examined by this method of starch analysis, proved to be composed entirely of dextrin, while other preparations of leaf starch consisted of over 90 per cent of starch. There is thus an enormous variability in the composition of the material which, on the basis of the iodine test, has been considered as starch. In view of the fact that starch may appear as transitory reserve material from which may arise, through the intermediary of the dextrans, a variety of substances of importance to the functional activity and to the formation of structural elements of the plant, it is important to follow more closely and differentiate more clearly the material which heretofore has been classed as starch. Consequently the freezing method for the isolation of starch-dextrin and the method of starch analysis have been applied to a variety of plant materials, including seeds, fruits, tubers and wood, with a view to examining somewhat more critically this aspect of the carbohydrate economy of these tissues. Some of the results of these investigations are now ready for publication.

#### THE CHEMISTRY OF THE CELL WALLS IN WOOD

One of the primary objectives of the cooperative investigations of Professors Bailey and Anderson was to determine whether polyuronides, more

particularly, pectic substances, as well as hemicelluloses are normal constituents of wood. The researches have involved the perfection of methods for the extraction, purification and the determination of the chemical composition of the substances in question. At the same time studies have been made of the distribution of these substances within the cellular tissue.

True pectic compounds, of fundamentally similar composition, have been isolated from woods of both Gymnosperms and Angiosperms. Included in these examinations have been the wood of the mesquite, lemon, black locust and white pine, and no wood thus far examined has failed to yield pectic material, though the amount present varies considerably in different species and in different parts of the tree. The composition of these pectic materials is essentially the same as that derived from a variety of soft, unligified tissues.

It is noteworthy that the available evidence indicates that the pectic substances originally present in the middle lamella and in the primary walls of the cambial region are carried over into the mature wood during tissue differentiation. There is no indication of the pectic substances having been transformed into or replaced by other substances during lignification, as has been frequently maintained is the case. The association of lignin with pectic compounds is of much theoretical interest for the study of the physiological processes involved in lignification and deserves thorough chemical investigation.

Hemicelluloses have likewise been isolated from the sapwood and the heartwood of both Gymnosperms and Angiosperms. The hemicelluloses obtained from hardwoods seem to be composed chiefly of compounds containing a uronic acid attached to a chain of pentose molecules; very little, if any, hexoses are present in these hemicelluloses. On the other hand, the hemicelluloses isolated from softwoods contain both pentose and hexose molecules. It is as yet not definitely determined whether these hemicelluloses invariably also contain uronic acids.

Owing to the variation in quantity and in chemical composition of the hemicelluloses derived from different woods, much additional work remains to be done upon this group. The hemicelluloses are apparently laid down in the secondary walls. After they have once been laid down in the wood it is doubtful whether they are transformed into lignin. It is, therefore, essential to establish their limits of variability and to determine more definitely their relation to cellulose, cellulose, lignin and other constituents of wood. An understanding of variations in the anatomical structure of wood, in its physical and mechanical properties, in its susceptibility to deterioration and decay, etc., in a large measure depends upon additional chemical data regarding this class of substances and its relation to the other constituents of wood.

The uronic acids are present in all pectic substances and in most hemicelluloses. They are characterized by the fact that, when heated with a solution of 12 per cent hydrochloric acid, they yield definite amounts of carbon dioxide. This property is made use of to determine the amount of uronic acid present in woods. About 100 different woods have been examined for their uronic acid content. The results indicate that the uronic acids do



not disappear as the wood ages and that they are present chiefly in combination as pectic materials and hemicelluloses.

## INVESTIGATIONS ON THE CAMBIUM AND ITS DERIVATIVE TISSUES

By I. W. BAILEY

Meristematic elements and such of their derivatives as retain a potentiality for growth and enlargement have a wall, *primary*, which is characterized by its capacity for growth and extension and for undergoing reversible changes, *e.g.*, in thickness. On the contrary, tracheary cells and sclerenchyma, which undergo irreversible changes and thus lose their potentiality for growth and enlargement, form a supplementary or *secondary* wall of fundamentally different physico-chemical constitution. During the last three years we have confined our attention largely to investigations concerning the visible structure, optical properties and chemical composition of the walls of tracheary cells and fibers. During the present year we have extended our investigations not only to cover the secondary walls of parenchymatous elements but also the primary walls of meristems and of other unligified tissues.

It is essential to secure more specific and reliable information regarding the physical structure and the chemical composition of primary walls as a basis for an adequate understanding of various aspects of growth and tissue differentiation. A preliminary survey of varied types of cells in different tissues and in plants of different systematic affinities indicates that, although primary walls vary considerably in thickness, in anisotropy and in chemical composition, they are characterized by having primary pit areas and plasmodesmata and a more or less finely lamellated structure. "Slip planes," which are present in the secondary walls of tracheary cells, fibers and parenchyma, appear to be absent in primary walls, suggesting a fundamental physico-chemical difference between the two categories of cell walls.

## EXPERIMENTAL TAXONOMY

By JENS CLAUSEN, DAVID D. KECK AND WILLIAM M. HIESEY

### PRINCIPLES AND PROBLEMS

These investigations, designed to attack the problem of natural relationship on an experimental basis and that of natural evolution by analytical and synthetical methods, entered a new phase in 1932 by the addition of cyto-genetical methods and of more intensive and extensive studies in standard environment gardens. It was soon found that the plant groups, which Dr. Hall had selected for the work, were admirably suited for the new approaches. But it became equally evident that this new departure required a revision of principles and of existing criteria of relationship. Consequently, a complete re-examination and re-cultivation of the materials, especially of the numerous races of *Madinæ* species, were necessary. The investigators started from certain working hypotheses based upon scattered experiments by various workers using various approaches. It had remained for someone to combine all of these approaches and apply them to

the same set of materials. The various lines of research used in this new branch of biology need to be adapted for this special purpose and coordinated with the others. Thus, genetics and cytology are not the ends but auxiliary disciplines, being subordinated to the study of relationship and evolution of the systematic units of plants. Likewise morphology, plant-geography and ecology are brought into harmony with the present-day cyto-genetic principles, based upon them and correlated one to the other. It was felt that the key to the understanding of relationship and evolution was to be found not in any single one of these principles but in all of them together.

The very existence of natural systematic units has been doubted by many biologists. It has been necessary, therefore, to show by experiment that groups of individuals are separated not mainly by conventional characters selected by taxonomists, but, in addition, by mechanisms inherent in their own structure that tend to keep them pure. This has put the species concept on an objective rather than a subjective basis. The controversial question of the importance of hybridization for the evolution of species has also been put to experimental tests.

Thus, major items of the present investigations have become: the outlining of principles and methods for a new discipline of experimental taxonomy, experiments on the natural species and other systematic units exploring their factual bases and characteristics, study of processes active in the evolution of species, and, as a result from these studies, the monographic treatment of plant groups.

### THE SPECIES PROBLEM

Extensive investigations have now tested the theories as to what constitutes a species. The work has shown that it is possible to give a fairly objective delimitation and classification of species based upon experiments rather than upon speculation, because there is a natural basis for species and other systematic units, which can be explored. Studies on systematic units of various order have revealed the following general trends.

Species are separated by genetic barriers of various degree and effect. Their hybrids are either partially or completely sterile, or, if fertile, most of the second generation shows a remarkable lack of vigor and would be eliminated under natural conditions.

Subspecies or ecotypes of a species show geographic or ecologic preference, and the characters distinguishing them ordinarily have selective value in their natural environments. They produce hybrids which are completely fertile and vigorous in both first and second generation. Lacking the benefit of any mechanism of genetic incompatibility, they keep pure only through their geographic or ecologic isolation, and, in places where they meet and cross, by natural selection. They may differ in as many genes as do closely related species, but lack the incompatibility mechanism characterizing these.

Varieties are neither geographically nor ecologically isolated and the characters distinguishing them have no selective value in the environment in which they live. They are usually spasmodic in their occurrence and several varieties may be found in the same locality. They differ by only one

or very few genes mostly affecting but a single character. Like subspecies they are completely interfertile and the second generation of their hybrids is as vigorous as the parents. Varieties have very little taxonomic or evolutionary interest but may serve a purpose in cataloging the most pronounced of local races.

The recessive "mutants" so commonly used in genetic investigations are seldom found in natural populations because of their inferior viability and vigor, but the genes for them are present in almost all populations of self-sterile species, and they are segregated when individuals from natural populations are inbred. They seem to have no evolutionary importance and should possibly be regarded as waste-products from the evolutionary processes. Some of the more viable of this category, such as color variations, are transitional to varieties, may persist over a period of years as elements of local populations and, if spectacular enough, attract the attention of collectors. Taxonomy, aiming at a classification picturing the units of nature, has no interest in spasmodic variations of this sort.

Characteristic of species as they exist in nature is that the genes controlling their morphology, physiology and development form an intricately balanced system ensuring inner developmental harmony and also harmony with their natural environment. Once a species is taken out of that environment the balance is somewhat disturbed, but the inner balance between various genes pulling in different directions still exists. Under natural conditions this balance is perpetuated from generation to generation through the chromosomal mechanism ensuring a relatively faithful reproduction of the genic structure for the species, which apparently is homozygous for all specifically essential genes.

This harmonious structure is not disturbed when varieties or subspecies of one species are crossed because of the homozygosity of those genes essential for the particular species. It is otherwise when different species are crossed. Although each of these is characterized by independently balanced sets of genes, the two will differ in regard to many essential genes, and it does not follow that these sets, when brought together in one organism, will produce a balanced or harmonious development. Moreover, if redistribution of the chromosomes is possible at the formation of sex cells in the first generation of the hybrid, the genic balance in the two systems will be broken up by the rearrangement giving many unbalanced and non-viable gametes, and, of the viable gametes, many will form non-viable or poorly balanced zygotic combinations.

This is vividly illustrated by the results obtained when species are hybridized. According to the degree of incompatibility, their hybrids give a graded series of disturbances. Some interspecific crosses are completely unable to pass beyond the stage of exchange of genes or to produce a second generation. In extreme cases species are so incompatible that no hybridization takes place; in others fertilization is possible but the development of the first generation hybrid stops in the early embryonic stage, giving shrivelled seeds unable to germinate. Others have seemingly good seeds which prove unable to germinate or the hybrid seedlings are dwarfish and slow-growing and never develop to maturity, but die before flowering. Some species will form

vigorous and normally flowering hybrids in the first generation, but they are entirely, or almost entirely, sterile because of complete elimination of gametes and zygotes. In this case balance and fertility can be restored by duplication of the chromosome number, but this will result in a new species, a new step in the evolution.

Other species are capable of exchanging a limited number of genes and will produce a vigorous first generation hybrid and some second generation offspring, but this is generally much less vigorous than the parental species. Some of these hybrids, partially sterile in first generation, will eliminate unbalanced combinations in the gametic as well as in the zygotic stage. They show aborted pollen and ovules, and shriveled or poorly developed seeds in the first generation, together with very poor germination and often many abnormal plants in the second. Still others have a slightly higher vitality, are very fertile in first generation confining the elimination to the second, but otherwise they are the same. Their second generation will largely consist of sublethals dying in seedling stage, of slow-growing dwarfs, plants strongly susceptible to disease, plants out of balance with the environment, of abnormals and subnormals less vigorous or less viable than the parents and unable to compete in nature, although they can be nursed along in the experiment garden. In both cases, a very large percentage of the hybrid product will be wiped out under natural conditions and the few vigorous offspring left will largely drop back into one or the other of the two original species, sometimes with one or a few genes from the other, thus increasing the variation and creating the phenomenon of parallel variation as described by N. I. Vavilov.

Species arrange themselves in natural groups depending upon a slight capacity for exchange of genes. A group of such species forming an evolutionary unit constitutes a cenospecies, using G. Turesson's terminology, or a species-complex. Members of different cenospecies are unable to exchange genes. The individual members of such a group are on the order of Turesson's ecospecies. These should be regarded as the taxonomic species because they represent the smallest units which keep apart by the aid of an inner genetical balance-mechanism. Studies of numerous species and hybrids have shown that the natural system in seed-plants is characterized by ecospecies that are grouped, in turn, into cenospecies. But there are many cenospecies that are not split into ecospecies, and incidentally these too are classified as taxonomic species. Such cenospecies often show very little variation, whereas those with many ecospecies are characteristic of seemingly youthful, aggressive and variable groups of plants.

The parallelism between the various taxonomic units suggests that ecotypes or subspecies in time become ecospecies, dependent upon the development of incompatibilities. Ecospecies, in turn, may eventually form cenospecies and the latter may be the nuclei for later sections or genera.

#### INVESTIGATIONS ON MADINÆ

Many facts of interest, links in a chain of evolutionary evidences, have been brought to light in addition to those bearing on the species problem.

Of these one example may be mentioned. A new amphidiploid species is emerging from a hybrid between two rare species, *Madia* (formerly *Layia*) *nutans* ( $n = 9$ )  $\times$  *M. Rammii* ( $n = 8$ ). It is of special interest that polyploids can arise from a single individual of a hybrid between two self-sterile species.  $F_1$  appeared sterile, but some akenes, developed by open pollination, gave a second generation of seven plants of which one was approximately triploid, six tetraploid or hypo-tetraploid. Two plants had  $2n = 34$  with almost perfect conjugation into seventeen pairs of chromosomes.  $F_3$ , developed from an isolated population of  $F_2$  including the triploid, is morphologically like  $F_1$  in its characters, as constant as any pure species, morphologically as distinct from its parents as any species of *Madia*, vigorous and healthy. The specifically different chromosomes did not conjugate in  $F_1$ , dyads with diploid or nearly diploid gametes were rather frequently formed, and the new species apparently arose from these near diploid gametes by self-pollination induced by pollen of the parent species and of the eight-chromosome *Madia elegans* (see Year Book for 1934, p. 175).

A work on Methods in Experimental Taxonomy is in the course of preparation that will give the principles for the new approaches and examples of their application. One volume will include a synopsis of the *Madinæ*, *Zauschneria* and the transplant problems and will contain also the discussion on these problems at the Conference on experimental taxonomy in 1934 (see Year Book for 1934, p. 171). A second volume of this publication will contain a more detailed survey of the results obtained in the first phase of the California transplant investigations from their inception by Dr. Hall in 1922, the manuscript for which has been prepared by Mr. Hiesey.

#### TRANSPLANT STUDIES

Some of the more important general conclusions from the transplant experiments were summarized in the Year Book for 1935 (p. 202). The accumulated transplant data furnish excellent background for studies planned to reveal interrelationships between morphological, cytogenetic, anatomical and physiological characteristics of plant forms from different environments. Correlations between the morphology of closely related forms within complex species and features of habitats which they occupy give assurance that new understanding of plant relationships and of processes governing plant distribution may be realized through coordinated investigations from different points of view on the same plant materials.

Steps toward intensification of the transplant experiments along these lines are gradually being undertaken. Material from transplants is being preserved for studies in comparative anatomy of races of the same species which originally came from different elevations, and for anatomical comparisons of clone-members of individuals transplanted to the Stanford, Mather, and Timberline stations. Consideration is being given to the development of methods for measuring certain physiological characteristics of transplants while growing undisturbed in gardens. A comparative study of some of these physiological processes may lead to the discovery of at least a few of the differences in function which make possible survival of

given types in certain environments. With this end in view, Dr. Mallery of the Desert Laboratory is continuing studies on the measurement of osmotic concentrations of expressed plant saps with transplant materials, and Mr. Hiesey is working on a quantitative field method for determining transpiration rates. *Artemisia vulgaris*, *Achillea millefolium*, *Potentilla glandulosa*, and *P. gracilis* are promising species for these studies. Methods for the study of physiological characteristics of transplants are necessarily of slow development. Complexities in morphology in polymorphic species, intricacies of their responses when transplanted to different elevations, and the multitude of variables which govern living processes make necessary critical and thorough investigation of any technique before it can be applied with justification to transplants.

The routine work of securing yearly transplant records at Stanford, Mather and Timberline stations is being continued. Emphasis is now being given to a study of differences in seasonal reactions between closely related forms originally from different altitudes which have been brought to a uniform garden, and to reactions of clone-members of individuals transplanted to different elevations. Differences of significance are evident. Thus, alpine forms of *Potentilla glandulosa* pass through their seasonal cycle from early spring growth to development of ripe fruit more quickly than forms from lower altitudes. This characteristic enables them to mature during short seasons. When transplanted to lower altitudes, alpine plants retain their rapid mode of development, but continue in active leaf growth for a longer period than is possible in their native habitats. Forms from the seacoast of central California grow more or less continuously during the year in their native habitats except for a short dormant period after flowering. At Mather, at 1400 meters elevation, their seasonal habits change to conform to their new environment; vegetative growth is confined to the snow- and frost-free period between mid-April and mid-October. When brought to Timberline, coastal plants develop too slowly to produce seed, and usually succumb the first or second winter after transplanting. Death seems to be at least partly due to the inability of coastal plants to synthesize and store necessary food reserves during the brief growing season lasting two months or less.

#### OTHER INVESTIGATIONS

Dr. Clausen and Mr. Milo S. Baker of Santa Rosa Junior College have continued the investigations on the two very complex cenospecies *Viola purpurea* and *Viola Nuttallii*, attacking the problems by field and herbarium studies and by cytological methods. About 2500 sheets of these two cenospecies were borrowed from various herbaria in the United States, examined, annotated, and the results mapped. *Viola purpurea* contains six ecospecies, three of which are new, and five new subspecies have also been discovered. *Viola Nuttallii* contains four ecospecies, one of which is new. There is a distinct correlation between chromosome numbers and geographical distribution. The evolution of the violets of these two cenospecies is seen as a response to the changes in topography and climate in the Western United States during recent geologic periods, which made new climatic niches avail-

able for occupancy by new species evolving by hybridization, genic recombination and polyploidy from pre-existing ones. Some of those are probably still living in the geologically oldest parts of the territory but are today very restricted in their distribution.

Systematic accounts were prepared and brought to publication during the year on the Hawaiian genus *Argyroxiphium*, formerly held to be of the Madinæ, but now excluded from the subtribe, and on two western sections of *Penstemon* by Dr. Keck. Taxonomic work on *Penstemon* is being continued.

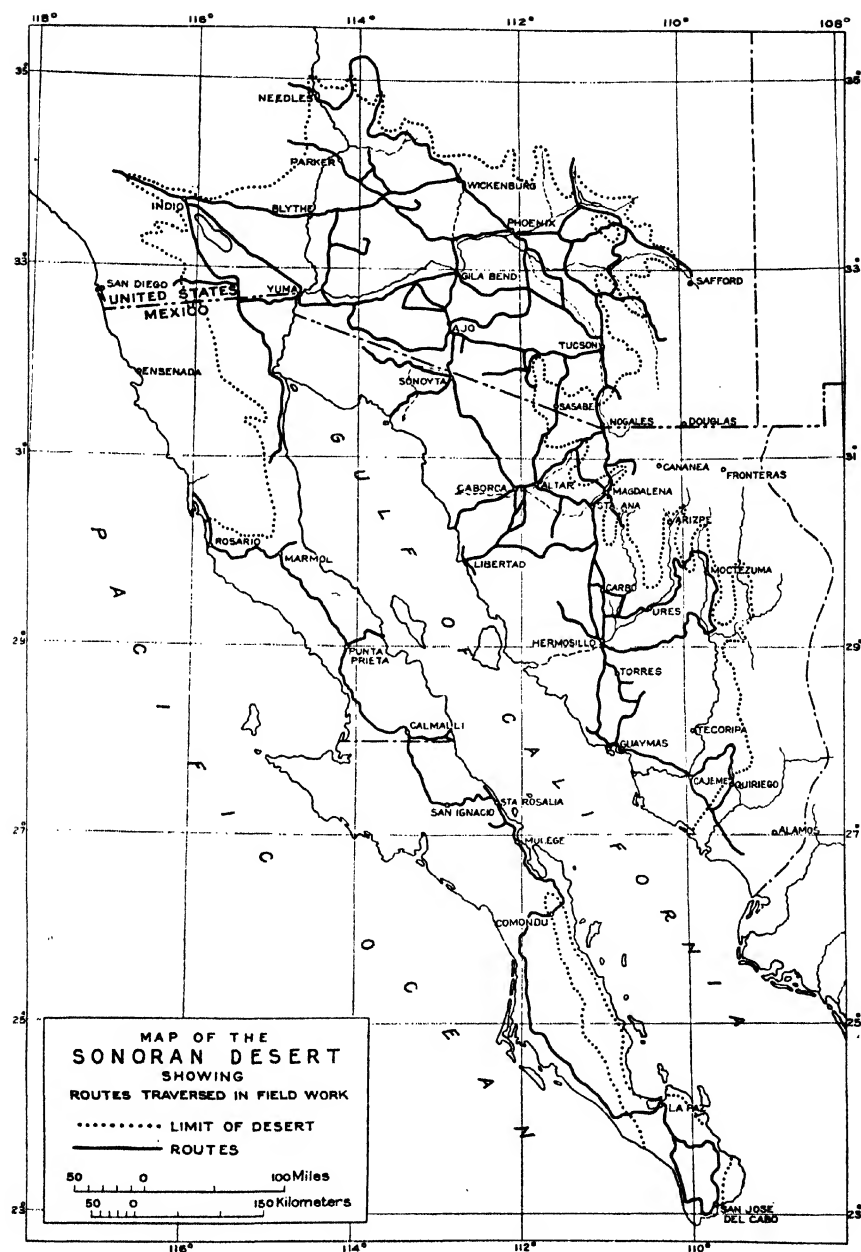
### DESERT INVESTIGATIONS

BY FORREST SHREVE, T. D. MALLERY AND W. V. TURNAGE

The study of the desert has much in common with the study of the sea. Both are wide in their scope and have many interlocking relations with the fundamental branches of science. From the biological standpoint eremology and oceanography are both concerned with life in a particular type of environment, with all of the aspects of such life, and also with its physical setting. Unlike as the conditions and life adjustments are in marine waters and on the driest parts of the land surface, there is a similar complexity of interdependences in the two fields.

The work of the Desert Laboratory has been planned and conducted with a vivid appreciation of the breadth of the problems of arid regions. In the prosecution of its program it is necessary to combine the viewpoints and methods of ecology, physiology, anatomy, phytogeography and taxonomy, as well as those of climatology, physiography and soil science. The aim of the work is not to investigate a particular condition, structure or process as an end in itself, so much as it is to learn the relations of these things to each other with reference to the continuity of life in the desert environment.

The work of the past year has yielded a number of facts and relationships which are of substantial value in the progress of the present lines of investigation. The exploration of the Sonoran Desert has been continued and considerable time has been devoted to the study and elaboration of the material and notes taken in the field trips of the last three years. Study of the life histories of poorly known desert plants has been continued, with principal emphasis on woody or succulent plants which are characteristic of the vegetation in the less accessible parts of Sonora and Baja California. Observational areas on the grounds of the Desert Laboratory, on which all perennial plants were charted from 8 to 30 years ago, have been re-charted and a study made of the changes which are taking place in the density and composition of the vegetation. Rainfall readings have been continued at the two lines of stations stretching from Tucson to the Gulf of California. Five new series of stations have been established for a short period for study of topographic influences and evidence of direction of approach of rain storms. The investigation of soil temperature which has been under way for a number of years has been extended to a closer examination of the range and extremes in the uppermost surface level in conjunction with readings in low air levels. The study of the osmotic value of the sap in *Larrea* and other shrubs has





been continued, and considerable work done in cooperation with the transplant studies which are being made at the central laboratory of the Division.

### FIELD WORK

Since the summer of 1935 field work has been confined to the interior of the Sonoran Desert in Arizona and Sonora, in a region with an annual rainfall of 4 to 8 inches. An expedition was made in the spring of 1936 through the largest of the previously unexplored areas in extreme northwestern Sonora. Dr. Shreve and Dr. Mallery were accompanied by Dr. I. L. Wiggins, of the Dudley Herbarium, Stanford University, and Dr. D. D. Keck, of the central laboratory of the Division. The rectangular area lying west of the 113th meridian between the International Boundary and the Gulf of California is characterized by extensive areas of dune and sandy plain surrounding the extinct Pinacate volcano and its lava field. Physiographic processes and soil conditions in the sandy region differ sharply from those in other parts of the Sonoran Desert, which has mainly a stony or hard surface. Wind predominates over water as an eroding agent, and the development of drainageways is poor or absent. The volcanic region is characterized by a very rocky surface, heavy soil and normal but juvenile drainage. A very considerable part of the volcanic field has been covered by wind-blown sand. Rain visits the region at rare intervals in both the summer and winter seasons. The winter temperatures are moderate, with occasional light frost, and the summer is long and hot. The vegetation of the sandy plains is a light cover of small shrubs in which only three species are abundant and of general occurrence. The dunes vary in their plant covering from nearly naked active ones to stabilized ones bearing a fairly heavy cover of the grass *Hilaria rigida* and the ubiquitous desert bush *Franseria dumosa*. The vegetation of the lava slopes and plains is much richer in individuals and species than that of the sand, but much poorer than it is in similar situations farther to the north and east.

Following the periods of adequate rain the dunes and sandy plains are covered with herbaceous plants in an abundance and variety which is in strong contrast to the poverty of the perennials. Some of these ephemeral plants are found on heavier soils throughout the lower elevations of the Sonoran Desert, while others are confined to sand in the regions adjacent to the head of the Gulf of California. All are characterized by speed of germination, the formation of a deep tap root, and rapid development to the flowering stage. The ease with which rain penetrates the sand and the effectiveness of the rapidly drying surface in preventing evaporation combine to give a brief period of very favorable conditions.

Additional exploration was carried out in the spring of 1936 in southwestern Arizona. Several of the broad detrital valleys and smaller desert mountains were visited between the Gila and Bill Williams Rivers. Interest in this region centers in comparison of its vegetation and flora with the similar plains 250 miles to the south in central Sonora and those 150 miles to the northwest in southern California. The effort is being made to secure evidence which will make it possible to distinguish between the plants con-

trolled in distribution by existing climatic conditions and those which are of local occurrence in areas of uniform conditions. The former group is of importance in investigating the relation of environmental conditions to distribution, and the latter group is calculated to furnish evidence as to the history of plant movements in the Sonoran Desert.

Dr. I. L. Wiggins is continuing his collaboration in the investigation of the Sonoran Desert and his work toward the preparation of a flora of it. He has participated in the field work, making such collections as the seasons permitted, and has made substantial progress in the study of earlier collections made by himself and others in the area. He spent December and January in the east, consulting herbaria in St. Louis, Chicago and Washington for the examination of types and the material available in difficult groups.

On the accompanying outline map are shown the routes that have been followed in the study of flora and vegetation in the Sonoran Desert up to July 1, 1936. Experience has shown that the amount of detail which is desirable in exploration is directly proportional to the topographic diversity of the various districts, and that this is true in the study of the distribution of plant communities as well as in the thorough collection of material for study of the flora.

During the spring of 1936, Mr. A. L. Hinckley examined and mapped the observational areas on the grounds of the Laboratory for comparison with the maps and lists of plants made in 1906, 1910, and 1928. These areas are permanently marked and share in the strict protection which is given the entire tract surrounding the Laboratory, but are not fenced against the visits of rodents. The collective data for the areas give a basis for studying the return of natural vegetation after the disturbances prior to the establishment of the Laboratory, the fluctuations in density and composition of the vegetation, the evidence for developmental or successional changes over long periods, and the comparison of the length of life of the common species. Most of the areas show changes in the composition of their vegetation during the last 8 years, and some of them exhibit a great increase in one or two of the species involved. On one of the areas there has been a large increase during the past 8 years in the number of young plants of *Isocoma Hartwegi*, which has long been regarded as multiplying rapidly only on overgrazed areas. During the last period of observation there has been a general increase of plant population, varying from 12 to 224 per cent, and a greater increase in the number of tussocks of perennial grasses than there was during the preceding 22 years. Some of the trees and larger shrubs have declined in numbers on certain areas, made no change on others, and in a few cases have made small gains.

The disturbance of natural conditions which the grounds of the Desert Laboratory had suffered before 1906 was partly restored during the 22 years from that date until 1928. The evidence is clear, however, that after 22 years of protection from grazing an additional period of 8 years without disturbance has resulted in further increases of plant population. This has taken place in spite of the fact that the final period has been marked on the whole by subnormal rainfall.

## ENVIRONMENTAL CONDITIONS

Dr. Mallery has continued the rainfall readings which are taken biennially in the sparsely settled region between Tucson and the Gulf of California and has published two papers containing a digest of the results from 1924 to the end of 1935. It has been well established that the rainfall along the Gulf of California is less than half as much as it is at the inland stations, which range from annual totals of 8 to 13 inches. Also the westerly stations receive more winter than summer rainfall, which is the reverse of the situation at Tucson and in that vicinity. These facts are reflected in both the abundance and the character of the vegetation found in the respective areas.

In order to make the study of rainfall of the greatest value in connection with biological work, it is necessary to know the means and extremes over a long period of years, as an indication of the fluctuating moisture conditions encountered by long-lived plants and as one of the basic conditions for their growth and distribution. It is also important to know as much as possible about the meteorological conditions which underlie the distribution of the rainfall in time and space. Knowledge of the sources of moisture, the movement of storms and the influence of mountains and broad valleys in causing local differences of precipitation are among the further objectives of the work. Dr. Mallery and Mr. Turnage have established five special lines of rainfall stations in the Santa Catalina, Tucson, Sierrita, Baboquivari and Tinajas Altas Mountains, aiming to determine the influence of these mountains on the precipitation of the adjacent plains, the influence of altitude and slope orientation on the rainfall of the mountains themselves, as well as the influence of the pitch of the mountain slopes.

The last four years of the record of rainfall at the Desert Laboratory made with a recording tipping-bucket gauge have been used by Mr. Turnage to make a study of the intensity of precipitation, of the frequency of rain storms at different hours of the day, and of the correlation between rain storms and wind velocity, as measured over the same period with a recording anemometer. The results are of importance in the study of the meteorological aspects of the rainfall work.

During the winter the nocturnal hours are more rainy than the daytime hours, but during the summer rainy season, from June to October, both frequency of occurrence and hourly amounts of rainfall are much the greatest between noon and midnight. Only about 10 per cent of the summer rain falls slowly as "warm front" cyclonic rain. The remainder falls as showers, about one-third of the total being in amounts of 0.20 to 0.60 inches per 15-minute interval. During the winter no "shower rain" falls in amounts as great as 0.15 inches per 15-minute period.

From March until July surface wind movement generally reaches a maximum in the late afternoon hours and a minimum between midnight and 10 a. m. June is the windiest month, the average maximum at 6 p. m. being 11.5 miles per hour, and at 3 a. m. being 3 miles per hour. From August to November there is a less marked daily variation in wind velocity, and during the winter there is very little difference between the average velocities at the various hours of the day.

The fortnightly readings of soil moisture at 8 depths to 6 feet which were begun on the grounds of the Laboratory in 1930 have been continued, in conjunction with measurement of runoff from the same soil. The earlier data, which have been published, and the later ones also indicate that this investigation will have increasing value if continued for a period of at least 10 years. It is now possible to make a very broad correlation between runoff and the intensity of rainfall.

Various aspects of the temperature of the soil have been under investigation at the Desert Laboratory for over 15 years. It is a condition of direct importance in the activities of plants, it has intimate relations with the amount and movement of moisture in the soil, and is a prime factor in its relations with the temperature of the air. Thermograph records are now being secured at the surface, and at depths of 3, 6 and 12 feet. From them it is possible to determine the prevailing temperatures to which roots are subjected at different depths, the rate at which the great daily and seasonal fluctuations at the surface are gradually reduced with increasing depth and the amount of lag in the soil maxima and minima. Determinations made in a humid climate in western Europe have shown a constant temperature throughout the year at 6 feet. The data already secured indicate that under desert conditions there is an annual fluctuation at 12 feet. At 3 feet there is no daily range but a slight weekly one. At 6 feet there is a very slight weekly variation and at 12 feet there is none. Readings at 6 feet have been secured for 4 years and show an average annual fluctuation of 19° F. Readings at 12 feet have been taken for only 7 months, but have already shown a range from 74° F. in December 1935 to 66.5° F. in April 1936. At present the readings indicate that the annual extremes of temperature at 12 feet lag from 3 to 5 months behind the extremes for the air, and that there is an annual fluctuation of 7.5° F.

Mr. Turnage has instituted readings of surface soil temperature and of air temperature at different levels in an investigation of the daily course of the thermal relations between air and soil. The difference between minimum soil temperatures and minimum air temperatures is greatest during the coldest periods of winter. On cloudy nights the two are approximately equal. During the winter the maximum soil temperature is seldom more than 10° F. above the air maximum, but in March the difference begins to increase rapidly. There is little seasonal change between the relations of the minima, but the maximum surface soil temperature rises during May and June to levels above 150° F. and occasionally as high as 165° F., or about 50° above the maximum air temperature. The surface soil warms rapidly after sunrise, increasing about 90° to the maximum about 2 p. m. By 3 p. m. cooling sets in strongly and by 8 p. m. the temperature has fallen from 50° to 60° below the 3 p. m. reading. Readings of surface temperature taken at night on mountains near Tucson do not bear out the view that a soil cold through radiation is responsible for contact cooling of the air and resulting cold air drainage. This phenomenon, of such great importance in the local distribution of plants, is more probably the result of subsidence and radiational cooling of air particles.

## BEHAVIOR OF DESERT PLANTS

Work is being conducted in greenhouse and garden and on the grounds of the Laboratory which is aimed toward securing a knowledge of the life histories and ecological relations of certain desert plants of which little is known except their names and taxonomic position. Many of the common perennials native to the Laboratory grounds have been studied from several angles for a number of years. Other species found only in the distant parts of the Sonoran Desert have only recently been brought under observation. Work on germination, behavior of seedlings and character of foliage has been continued. Species of *Bursera* and *Jatropha* in which the cortex is greatly enlarged are found to develop this characteristic in a very early stage. Seedlings of *Idria* are also found to develop the enlarged pith and stout stem characteristic of mature plants. The transition from leafy seedlings to the naked green-stemmed form is being followed in several species. The early development of a large storage root is being studied in *Ceiba acuminata*. The development of the globose and partly buried stem of *Ibervillea sonora* is being followed. Adequate investigation of the anatomy, physiology and field relations of the plants now under observation would undoubtedly broaden greatly our knowledge of the adjustments which plants have made to the desert environment.

In connection with mapping the geographic distribution of the characteristic woody perennials of the Sonoran Desert, special attention has been given to the species of *Franseria*, a large genus of the Compositae, which reaches its greatest development in this area and furnishes several of the most abundant components of the vegetation. Data on distribution have been compiled from field notes, published references and specimens in six of the larger herbaria. The geographical limits of the species are being studied in connection with their relationships and essential characters. The ecological features of their distribution are being investigated from every angle. The group is being viewed both as a taxonomic unit and as a highly plastic element of the vegetation. Considerable additional work will be required on the ecological behavior of *Franseria* before it will be possible to identify the conditions that have given the genus its present wide range, wealth of forms, restrictions to habitat and pattern of distribution.

In conjunction with the field work in the Sonoran Desert, Dr. Mallery has been continuing his investigation of the osmotic value of the sap of several widely distributed perennials. This work constitutes an attempt to evaluate climate in terms of plant response. Since moisture is the dominant variable environmental condition on the desert, it seems desirable to seek a possible correlation between sap concentration and rainfall. In effect, the plants themselves are being used in measuring the effectiveness of the environmental conditions which most directly influence the water relations.

Evidence has been secured during the year which indicates that different types of soil are not responsible for differences of osmotic value in *Larrea*. These results were obtained from two series of plants which had been growing for 5 years in prepared soil plots, one series being in the open and the other under a screened lath shelter. The determinations were made at a time of se-

vere aridity and uniformly low soil moisture in all of the plots. The soils comprised crushed caliche, half caliche-half adobe clay, adobe clay, sandy loam of low salt content, and sand. No significant differences of osmotic value were found between the plants raised in the different soils nor between those in the light shade of the shelter and the open.

## ECOLOGY

ADAPTATION AND ORIGIN BY F. E. CLEMENTS, F. L. LONG AND E. V. MARTIN

In accordance with the synthetic approach to the problems of adaptation, the endeavor is made to carry forward the study of factor, function and form as simultaneously as possible. This frequently requires the development of new instruments or the modification of existing ones, as in the present instance. For the transplant gardens at Pikes Peak and Santa Barbara it is essential to secure a continuous record of solar radiation throughout the growing seasons. After much experimentation, photocells have proved incapable of yielding comparable measurements and recourse has been taken to a slight modification of the pyrliometer, partly to avoid the heavy expense associated with recording instruments of this type. The sensitive element consists of a black and white silver ring enclosed in a lamp bulb, and a series of thermocouples registers the temperature difference between the two generated by radiation. The emf developed is then recorded photographically on a revolving drum by means of a reflecting galvanometer.

A battery of six ecostats for the control of soil temperature has been installed in the experimental garden at Santa Barbara. These consist of vats 4 feet square and one foot deep, capable of holding 16 phytometer containers. They are filled with water, the temperature of which is thermostatically controlled by means of refrigerating and heating elements to yield any desired set of conditions between 32° and 120° F. Since the ecostats are insulated in the open garden, the aerial factors of the phytometers are not altered. During the winter months at Santa Barbara, the average air temperature is not more than 3 to 4 degrees above that at the Alpine Garden on Pikes Peak for the summer, and hence the ecostat series can also be employed to throw light upon the rôle of soil temperature in alpine dwarfing.

In the further application of the phytometer method to the measurement of functional responses in the climatic and edaphic gardens, a number of additional species have been tested, partly to supplement *Helianthus* and partly to replace it at high altitudes and in deep shade. The correlation of sealed and free phytometers has been rendered more exact by growing them in the same soil and placing a battery of the free ones in the soil of the experimental habitat. The inquiry into the distribution of water and roots in the containers has been continued by sectioning the soil-cores at 1-inch levels, with the result that both prove to be highly uniform from top to bottom and from center to circumference. In accordance with these tests, two comprehensive installations have been made in the adaptation series of gardens at Santa Barbara and in the transplant series at the Alpine Laboratory, for which it has been necessary to transport large amounts of soil. In the first, soil

from each of three habitats, namely, control garden, mobile dune and stable dune, has been placed in pits in all three to accommodate the free phytometers, along with a battery of sealed containers comprising the same soils. In the transect from plains to tundra at Pike's Peak, the organization is similar, but there are 3 to 5 batteries in as many edaphic habitats of the three major climates.

The studies in periodism have been carried forward at both laboratories during the respective seasons. These deal with species from three climaxes, namely, tundra, prairie, and deciduous forest, those of the first two being interchanged at Pikes Peak, while all three are represented at Santa Barbara, some watering being necessary in dry seasons especially. In the approximately 300 species concerned, the time of appearing and blooming can be shifted from one to six months in accordance with the temperature difference, both climatic and seasonal. Water is chiefly important through its conjunction with rising temperatures, though low values hasten flowering, while length-of-day as such appears to be without effect. A number of alpine blossoms at Santa Barbara during the shortest days of the year, but on Pikes Peak they flower in late June and July. A similar relation obtains between the mixed prairie at 6000 feet and the alpine tundra at 12 to 14,000 feet; alpine transplants to the plains bloom 2 to 3 months earlier than their congeners in the tundra, and plains species taken to the summit unfold their flowers 1 to 3 months later than in their own climax. Similarly, such species as *Caltha palustris* and *Iris versicolor* brought from the East and grown at the Alpine Laboratory at 8000 feet bloom around the June solstice and much later than related native species. Furthermore, length-of-day appears to be without significance for more than a hundred forbs and grasses that range from Texas to Manitoba and Saskatchewan, the time of blooming marching with rising temperatures to the northward, as it does likewise with increasing altitude. A relevant fact is the irregularity in the return of migrant birds, which is timed by temperature and the related periodism of food plants and not at all by length-of-day (Clements and Shelford, "Bio-ecology").

An intrinsic part of the adaptation series each year is the continued testing of the assumption that adaptation is a static condition, being merely the survival of favored genetic strains and not a dynamic process characteristic of all organisms. The number of individuals of each species for the various conditions is determined at three different times during the growing season and in practically all cases survival has equalled or exceeded that of the control beds. Under extreme conditions, such as 3 per cent shade or mobile dune-sand, the rule is that all individuals of the less resistant species disappear. Even more eloquent is the fact that clones or divisions of the same plant often suffer a higher mortality than plants grown from open or selfed seed. Furthermore, there is no discernible difference in the survival behavior of the individuals of the last two groups, in spite of the assumption that selfing tends to eliminate genetic strains.

In the transplant gardens, special attention is being paid to the question of alpine dwarfs, which are regarded by the ecologist as ecads and by some geneticists at least as ecotypes, the essential difference being that of fixity or

heredity. The evidence so far secured suggests that these are not two wholly separate units, but that the one passes into the other as the particular habitat continues to operate. Most alpine species brought down to plains or sea-coast lose the dwarf habit slowly year by year, though the change may be effected in a single year by reducing the light intensity, increasing the soil-water or adding fertilizer. However, transplanting plains or montane species to the alpine climax results in the production of dwarfs the second season in practically all cases, though this effect too may be largely or wholly inhibited by shading, watering or fertilizing.

Modifications of various sorts, including convergences and conversions, continue to accumulate in the transplant gardens in accordance with the factor and dosage employed, or in response to controlled competition within the plant body. As an illustration of the latter may be cited the case of *Thalictrum sparsiflorum*, in which compression of the stem reduced access of food to the flowers and the pistils failed to develop in consequence. This experiment in phylogeny strongly suggests the manner in which the dioecious *T. Fendleri* of the Rocky Mountains was evolved from the circumpolar *sparsiflorum* with bisexual flowers. The alpine dwarf, *Senecio taraxacoides*, has again been converted by means of shade into the probably ancestral *amplectens*, which lives in the adjacent spruce forest. Four generally accepted species of *Stipa*, namely, *viridula*, *Vaseyi*, *columbiana* and *Lettermani*, have been variously modified to overlap or duplicate each other, indicating that the last three are recent derivatives of *viridula* and to be treated as subspecies of it, an assumption confirmed by their respective habitats. Even more significant has been the natural conversion of *Stipa comata* into *spartea* along the sandy escarpment of the Painted Desert; these have always been regarded as distinct species, but the accumulated evidence supports the view that the latter is a mesic variety of the former, representing it as a eudominant in the moister true prairie.

#### CLIMATE, CLIMAX AND SUCCESSION, BY F. E. CLEMENTS AND E. S. CLEMENTS

The use of the sunspot cycle to forecast the rainfall of the following season or year was justified by the generally average rainfall for the Pacific Coast and the country at large in 1935. On the basis of the same principle and its corollaries, more or less normal precipitation was to be expected during 1936; the verification of this was general for the Pacific Coast, in spite of a high degree of spottedness. In the Middle West, this feature was even more marked and the distribution in time was still more varied, with the final outcome in doubt during early July. The wide discrepancy between regions was attested by the occurrence at the same time of critical drouth in the Dakotas and serious floods in Texas, and this helps to confirm the feeling drawn from the experience of the past six years to the effect that distribution in time and space is of equal importance with the annual trend of rainfall. It is hoped that the present digest of the rainfall of North America, which is being prepared through the cooperation of the California Forest Experiment Station and the Scripps Institution, will afford some light upon these perplexing problems.



The significance of the divisions of the climax as indicators and measures of subclimates, regional and local climates has emphasized the importance of drawing the boundaries of the associations more closely and of sketching in the respective subdivisions, *i.e.* faciatiions and lociations. These are likewise necessary for forecasting the type and rate of natural recovery, as well as the dominants to be preferred in regeneration by seedling or planting, especially by the method of artificial succession. It is furthermore indispensable to distinguish the types or communities actually on the ground as climax or proclimax, and to separate the latter into disturbance or disclimaxes, sub-climaxes, etc. Since the major task in conservation is to undo the harm wrought by man, it is of the first importance to disentangle the disclimaxes from the climax proper so that remedial measures may reckon with all the processes and factors concerned. This is particularly essential for the restoration of wild life, a task that is still too much characterized by the quest for a panacea. An adequate and prompt solution of this problem can be found only by thorough investigation of the rôles assumed by the various animals in climax and sere and their response to disturbance processes of all kinds. Climate, cover or shelter, food supply, disease, and predators, including man, must all be assessed at their proper value in the synthesis that expresses itself in the cycle of numbers.

The application of ecological methods and processes to the national projects in conservation has been broadened and deepened during the past year. Especial consideration has been paid to the process of natural recovery, which is essentially a matter of secondary succession. The course of this is quite different in abandoned fields from that in pasture and range, and it differs again in its details from one division of climate and climax to another. However, its two major features are universal, in that disturbance or destruction must first cease more or less completely and movement of populations to or toward the climax be resumed. Artificial succession or regeneration is similar in character, but possesses the great advantage that an adequate access of seed is assured. It profits much and often decisively also by telescoping the sere into one or two stages as a rule, by selecting the most desirable dominants for the particular site, and by using mechanical methods of preparing a seed-bed and insuring a larger supply of soil moisture.

In order to secure these results in the highest degree, the subfurrow has been devised to supplement the contour terraces regularly employed in field and pasture to minimize runoff and erosion, and consequent flooding, and to hold the water on the slopes to improve growth and germination. The subfurrows are adjusted in number and depth to the gradient, cover and interval; they serve not only to distribute the water more uniformly; but they apportion the seed-bed and at the same time reduce the flooding and puddling along the terrace. The same mechanical pattern may likewise be applied to the reclamation of top-soil dunes, but it is far better to level and redistribute these in so far as possible. In the case of the far-flung dunes of the "dust-bowl," this task might be accomplished by steam-shovels, but only at a cost excessive even under present conditions, and hence recourse is to be taken to the ecological method of using the wind to undo its own handiwork. In order to supplement the blast action on the dunes by cutting off the supply of mate-

rial, lister furrows are run along the eroding edge and at intervals over the plain of drift.

The organization of the field of bio-ecology has been completed in cooperation with Dr. Shelford, and the manuscript is now being prepared for publication. Although the major problem has been to outline the structure and development of the biome or biotic climax, new ground has been broken in the account of community functions, such as aggregation, competition, disoperation, migration, and cycles. The supposed regularity of returning migrants has been shown to be mythical on the basis of long-term records, and it is concluded that migration itself is a primary response to changing temperature and food-supply. With respect to cycles in animal populations, it is found that the so-called "crash" at the minimum is practically non-existent, the fall to the minimum and the rise to the maximum occupying much the same period of time.

In the field of paleo-ecology, a new concept, that of the "transad," has been developed and gives promise of greatly increasing the scope and definition of the principles laid down with respect to past vegetation in "Plant Succession" (1916). This has been developed as the major theme of a recent study of the origin of the desert climax and climate, and the idea of the transad is being employed on a larger scale in the investigation of the paleo-ecology of western North America in collaboration with Dr. Chaney. The high lights of this treatment are now in press under the title, "Environment and Life in the Great Plains."

## PALEOBOTANY

BY RALPH W. CHANEY

Studies of Cenozoic plants have continued along the lines described in previous reports and may be summarized as follows.

R. W. CHANEY—The problem of distribution has long occupied the attention of students of modern plants. Some consideration has been given to the distribution of fossil plants as well, but for the most part this has been cursory and unrelated to the study of the range of modern vegetation. During the summer of 1935 a survey of the distribution of forests in Mexico has resulted in the accumulation of data which are significantly related to those of the past. The subtropical vegetation from the lowlands up to an elevation of about 4000 feet is similar in character to fossil floras from Eocene deposits in western America. Farther up the slopes, with its best development at about 7000 feet above sea-level, a temperate forest contains many of the genera which characterize the Miocene floras of Oregon and adjacent states. Still higher, though rarely well developed, is an open type of forest, of a cool-temperate and semi-arid type, which contains many of the modern equivalents of Pliocene trees.

Northward from the Plateau of Mexico the subtropical forest of the lowlands disappears as a result of cooler and drier climate. The temperate forest persists at favored situations in mountain canyons and in somewhat modified form occurs northward along the mountains and down to sea-level on the California coast and into Oregon. There is no reason to believe that

latitude and altitude have not always played an important part in determining the character of vegetation. Actual proof of the differentiating effect of latitude may be seen in the temperate aspect of the Eocene flora of Alaska, in striking contrast to the subtropical forests which occupied Oregon at the same time.

The application of such simple concepts to palæobotany may be expected to eliminate many of the inconsistencies relating to the age of plant-bearing rocks. Two fossil floras may have elements in common, but if they occur in regions of different latitude their age may be established as different. The trend in environment during Cenozoic time, from a warm, moist lowland with oceanic climate to an emerged land mass characterized by greater extremes of temperature and precipitation, is directly related to major earth movements in western North America which have built up the continent to its present state. The climate at any given level in the Cenozoic is judged from the nature of the fossil plants, after corrections based upon the latitude of their occurrence have been applied.

An example of such procedure may be seen in a recent study of a Cenozoic flora from Oklahoma, in cooperation with M. K. Elias, who collected most of the fossil specimens. The temperate character of this flora suggested its middle Cenozoic age; many of the species have been recorded from the Miocene of Oregon; but there was missing the redwood element so characteristic of the Miocene farther north and in its place a number of stream border species suggested reduced precipitation. A later age was indicated by the occurrence of this modified forest of "Miocene" aspect because of its occurrence some 500 miles south of the typical Miocene areas. The reference of these fossil-bearing beds to the Pliocene is consistent with the climatic and distributional data of the land plants as well as with the evidence of associated diatoms and mammals.

Investigations of several associates and students at the University of California have been supervised, as follows.

E. DORF—The study of a flora from the Idaho beds of west central Idaho serves as a basis for referring these beds to an age transitional between the Miocene and Pliocene. The vegetation had many of the characters of the Miocene of the Columbia Plateau region but is definitely younger in terms of the climatic trend.

H. D. MACGINTIE—A flora from Trinity County, California, contains elements of the older subtropical forest which survived adjacent to the coast; other genera are of a more temperate character, as is consistent with the trend toward a cooler, less humid climate. Manuscript of the paper discussing this Oligocene flora has been submitted for publication.

L. H. DAUGHERTY—The relation of woody, foliage and fruiting structures collected from the Triassic of the Southwest is adding significance to the increasing list of species from this little-known flora.

C. CONdit—The survival of warm-temperate plants into the Miocene of the San Francisco Bay region is indicated by a study of the San Pablo flora. Eastward, where the influence of the ocean was less effective, the vegetation of this period was strictly temperate.

D. AXELROD—A further study of the Mount Eden flora from the Pliocene of southern California has been made in cooperation with Mr. Childs Frick of the American Museum of Natural History. This flora contains elements which are now distributed in the canyons of arid areas extending down into Mexico. Preliminary work has been begun on Miocene floras from southern California.

B. B. WILDER—Systematic collecting in the travertine deposits at Yellow Springs, Ohio, will serve as a basis for a more complete knowledge of the vegetation in Ohio during the past several thousand years.

Studies of Mesozoic plants have been begun in the Rocky Mountain province, where Dr. Dorf has made extensive collections and observations in the Cretaceous. Since the plants of this period are ancestral to those of the Cenozoic, an understanding of their distribution and relationships is essential.

### CLIMATOLOGICAL RESEARCH

By A. E. DOUGLASS

#### FUNDAMENTAL STUDIES

To extend our fundamental knowledge of tree rings and their use in climatology, we have made in the past year additional observations upon the amount of uniformity in ring sequences about the circuit of trees growing in the areas producing our long chronologies. Uniformity means in this case that the relative thicknesses of the rings (not the absolute thickness) taken in sequence from the center to the outside are essentially the same in all directions from the center and at different heights in the stem of the tree. For the purpose of examining this matter, several trees near the forest border east of Flagstaff have been tested for uniformity in the vertical; numbers of sections have been measured in different radials and great numbers have been examined for continuity of individual rings about the circuit. We find that while roots and branches are less certain, uniformity throughout the stem is especially strong in the sensitive tree records preferred in chronology construction. These results support our conclusion of twenty-five years ago that successful cross-identification in a large percentage of trees over a great area (hundreds of thousands of square miles) is in itself convincing evidence that the trees have a high degree of uniformity within themselves.

In sharp contrast to the uniformity found in the trees of our semi-arid plateau areas is the lack of uniformity in certain coastal trees of California, observed by MacDougal and Shreve and confirmed for certain areas by our own collections. That condition, however, was not unexpected at the start of tree-ring work and it was the contrary condition found in northern Arizona that stimulated the study in these regions. It was many years later—perhaps even quite recently—that we realized how great is the uniformity both within the trees and between different trees in our area. It is likely that this region is exceptionally favored in this particular respect.

Fluted trees, such as some of the junipers of our dry areas, are not necessarily lacking in circuit uniformity if one realizes that identification should be attempted in the radials of thicker rings that constitute the "convex" areas of the circuit. Reinforcement of rings (compression wood) develops when

the tree is growing under strain, commonly from gravitational sources. This happens constantly on the under side of branches and occasionally in stems, especially when the tree is small. This reinforcement has usually made the ring sequence unreadable, since the added growth on one side is often accompanied by diminished rings on the opposite side. Similar effects appear in fire injuries. Extraordinary cases of reinforcement sometimes circle the tree in a spiral (illustrated in trees from Sweden and Alaska) which is extremely difficult to explain.

### CLIMATIC INFLUENCE IN TREES

In preparing the long Arizona chronology, to which a reference will be made below, it has been necessary to review some thousands of specimens for the purpose of selecting those individuals that give the best sequences, that is, those showing the more typical cases of variation and those most free from injury and difficulties caused by missing rings. On looking over this large number, one's earlier conclusion is renewed that the different sequences may largely be classified in terms of complacency on the one hand and sensitivity on the other. There are very few distorted or disagreeing sequences; most cases of unidentifiable ring series come from that lack of variation from ring to ring, which we call complacency. Sensitive sequences show the sort of variation that is found to occur from year to year in our winter rainfall. That has led to the provisional use of four classes or types of sequence, as follows: (A) Highly sensitive with strong differences between almost every two successive rings; (B) sensitive, but with groups of five or ten or more rings of nearly equal size; (C) all complacent, but with individual dating checks sufficiently frequent to identify the rings; and (D) too complacent for identification.

All the dated specimens and a few others have been marked in terms of this classification. Approximately 650 specimens have been set aside for use in the chronology. Of these about 18 per cent are classed as A type, 55 per cent B type, 25 per cent C type, and 2 per cent D type. The last group contains about a dozen, of which a part are really dated and classed as between C and D types and a part, whose age is known to the nearest century, will give information about the age curve, that is, the changing rate of growth of the tree with age. The relative size of these classes in the various locations from which the specimens came will aid in determining more exactly the topographic character of the sites in which the trees grew.

Viewed from a practical point we see that these characters offer a classification of specimens based on internal features by which those specimens giving better climatic records can be selected for measurement and study. After all, this gives us only a statistical basis for the preference we have partially recognized for years but have rarely used.

### CYCLE STUDIES

In view of the formulation now made of our cycle studies (Vol. III, Climatic Cycles and Tree Growth), it is not necessary to go into details beyond two or three points. The first is to emphasize the value that seems to exist

in the frequency periodogram for securing evidence of the relation between solar and terrestrial changes. This is a periodogram that depends on frequency of occurrence of various cycle lengths in large groups of sequences, such as in various ring records. It is difficult to see how this method of cycle comparison could be carried on practically in any other way than the one used in our laboratory. But we realize that a large part of the world's records still awaits the application of these tests. The second item refers to extension in time. We need other long chronologies for carrying out such tests elsewhere in the world for past centuries. Our long chronologies are further useful in trying out systematic attempts at various techniques of prediction.

Reference should be made here to the seemingly worth while use of our method of cycle analysis in the long series of observations upon the International Magnetic Character Figure C. This form of analysis being specially adapted to showing cycle lengths, readily differentiates between different rotation periods of the sun when applied to the magnetic data referred to.

#### LONG CHRONOLOGIES

The extension of our long Arizona chronology back to A. D. 11 was referred to in the 1934 report. It was strengthened further in 1935 and with the more intensive examination of the specimens now appears almost certainly free from errors of identity. When the ring records of some hundreds of specimens are massed together in a plot, showing their extension in time, there are evident certain banks of years thickly covered by specimens, and between these banks the intervening points are represented by comparatively few records. This banking of records, viewed in one way, points back to the four large floating sequences with which the writer struggled in first extending the long chronology back before 1300. The less well-filled points of contact between the banks have historic and climatic significance. One of them was at the time of the great drouth in the late 1200's and was caused by it. This drouth was a calamity to the peoples living in the dry Southwest and was connected with, we think, the profound change in cultures from Pueblo III to Pueblo IV. Another occurred in the early 1100's, in the later part of the "Classical Period;" a third was near 700, probably at the time the "Basket Makers" were taking on Pueblo culture; and a fourth was in the early 500's, at a time not yet expressed in culture change. The identification of building dates as early as A. D. 348 and 352 and other times in that century make it seem worth while to attempt the special preservation and possibly the restoration of some of those early settlements. While these points of jointure have fewer specimens covering them, they present no cases of doubt as to the continuity of years across them. This is because they are usually drouth periods and the quality of the records that pass through them is very high. However, for the sake of uniformity in the whole sequence one desires to add other dated records of all types at these particular points.

It is not easy to see at this writing how additional records will be found for the great drouth in the late Thirteenth Century within our Central Pueblo area. We have confirmative records from three points outside this area and

others, I am sure, will be found. The contact point in the 1100's will probably be covered by a number of long records from Mesa Verde in southwest Colorado and the Segi region in northern Arizona. Great numbers of specimens from Wupatki, near Flagstaff, are found in it, but that is outside our area. The point near 700 has some excellent juniper records passing through it; they confirm, but do not improve, our pine and Douglas fir records. We realize that A. D. 700 is rather far back to permit us to expect much additional material, but the Flagstaff region is aiding in this respect, though outside the desired area. The point near 500 will be harder to fill with additional records, perhaps because it differs from the other points in showing long periods of complacent growth. A promising region to look for aid is Mesa Verde, whose "Earth Lodges" were built in the early 600's.

It is important to note that recently acquired equipment for photographing ring records has been installed and Mr. Davis has been getting highly gratifying pictures to place our long chronologies in suitable form for permanent record.

#### STAFF

Dr. Glock has written reports of dissected trees and has aided in the preparation of the volume on cycles. He has carried on studies of tree-ring growth and climatic elements, with a view to the use of the former in the estimation in past climates. Mr. Schulman has worked through numerous cycle problems with or for the writer, with special reference to the volume on that subject, and is now engaged in testing techniques of prediction in our long chronologies. Mr. H. F. Davis is devoting himself entirely to photography with very satisfactory and important results, for these excellent copies contribute to the permanence and usefulness of our ring chronologies. We have had important help, also, from Mrs. G. Dewey and Mr. Arthur N. Cowperthwait in studies of the Magnetic Character Figure C, and from Mr. C. G. Keenan in the construction of apparatus, and from others in typing and so forth. Some twenty-five hundreds of hours of aid has been received with appreciation from Government sources. These workers in FERA and NYA have been under the direction of Dr. Glock and Mr. Schulman.

#### COOPERATIVE WORK

The cooperative arrangement between the Carnegie Institution of Washington and the University of Arizona has continued through the year. Work has been carried on in quarters at the latter place during the winter months and at the Carnegie Laboratory at Stanford University in the summer. Photographic facilities and office room have been generously placed at our disposal by the Desert Botanical Laboratory of the Carnegie Institution at Tucson.

# DEPARTMENT OF TERRESTRIAL MAGNETISM <sup>1</sup>

JOHN A. FLEMING, DIRECTOR

O. H. GISH, ASSISTANT DIRECTOR

## SUMMARY

Terrestrial magnetism and terrestrial electricity each present a basic problem, namely, that of the origin and maintenance of the Earth's magnetic and electric fields. These problems have so long baffled investigators that some deem it necessary for their solution to postulate an entity which may hold the key to both problems but which is as yet unknown to physics. Others continue to expect that, as the details of the phenomena become more completely known and are adequately integrated, a solution requiring no new postulate will be evolved. On the first view, investigations of the fundamental constituents of matter and their interactions would hold promise of indicating the way to a solution of these age-long riddles. On the other view, present attention should rather be directed toward obtaining more information about the phenomena themselves and about other gross geophysical features upon which these phenomena depend. Taking cognizance of these two views, the work of the Department is designed to embrace both, and to cover the middle ground between them in so far as that is possible.

In the investigations dealing with the fundamental properties of matter a new physical force of universal importance was directly observed and measured for the first time in the Department's laboratory during this report-year (July 1, 1935, to June 30, 1936). This force, like gravitation, is a basic characteristic of all material things. It is the attractive force between the primary constituents of matter, which binds these protons and neutrons together to form the atomic nuclei of all the chemical elements. This is a most outstanding result, realized from the nuclear-physics program which was begun at the Department in 1926 with the objective of disclosing fundamental facts bearing on the intrinsic nature of magnetism, and which is considered important in arriving at an understanding of the magnetic and electric fields of the Earth. Utilizing the high-voltage equipment and technique developed for such investigations, it was established that when the distance between a pair of protons is extremely small this attractive force predominates over the electrical repelling force. A far-reaching simplification emerged when analysis of these experiments showed that the attractive forces between a pair of protons, between a pair of neutrons, and between a proton and a neutron are evidently identical. These binding forces within atoms are clearly among the few most fundamental forces in Nature.

In addition to these investigations of the microcosmos of the atomic nuclei, the Department pursued its program for investigating the Earth's magnetic and electric condition through observation of the experiments performed by Nature free of the controls exercised in laboratories. Continuous registrations of the magnetic and electric state of the Earth and of its atmosphere

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were obtained at the Department's observatories, while reduction and interpretation of the results were conducted at Washington. Although the cause of the permanent magnetic field of the Earth has not yet been determined, definite progress has been made in the understanding of its fluctuations.

All known fluctuations of the Earth's field except those of long period—that is, the secular change—are demonstrably due to two causes; one acts above the Earth while the other acts within it. The more rapidly varying aspects of magnetic effects of internal origin seem attributable to induced electric currents circulating within the conducting substance of the Earth. Manifestations of these earth-currents have been registered at the Department's observatories for more than a decade. Through cooperation with other organizations, similar registrations have been obtained from several other widely separated places. Thus, during the past year, it became possible to construct a world-map of the electric currents circulating within the Earth and of their shift from place to place throughout the day.

From magnetic observations alone, modes of circulation of electric current in the atmosphere and in the Earth may be inferred. Such current-systems, both inside and outside the Earth, which would give rise to the world-wide features of magnetic storms were constructed by formal mathematical analysis. They revealed that the currents circulate about the geomagnetic axis of the Earth with maximal densities of flow in the tropics and in the auroral zones. The currents which would give rise to magnetic "bays"—fluctuations in the Earth's magnetism of duration about an hour, more or less—have also been inferred. The principal aspect of these currents is a westward flow in the high atmosphere along the auroral zone on the dark side of the Earth with the associated return flow in the high atmosphere and the concomitant currents induced within the Earth. The hypothesis has been advanced that these currents are caused by movements of the atmosphere through heating where auroral displays occur.

That the atmosphere may have the required properties for the transmission of such currents in its outer limits at a great altitude—designated the ionosphere—was first indicated by the phenomena of terrestrial magnetism itself and independently, many years later, by the propagation of radio waves. The pioneer experiments began in 1925 at the Department, and subsequent developments there have resulted in equipment and technique for more precise investigations of the ionosphere by radio methods. With these methods and investigations, the first rather vague qualitative concepts of the ionized upper atmosphere have progressed to a more sharply defined quantitative concept of several major ionized regions. Each of these, while merging into adjacent regions, has certain specific characteristics, a knowledge of which is fundamental to theories of the magnetic fluctuations. Already the ionospheric observations have supplied some basis for discriminating between certain theories of the regular diurnal fluctuations in terrestrial magnetism and have supplied supporting evidence for the theory proposed to explain magnetic bays.

While the region of the atmosphere below the ionosphere may play no part in the phenomena of terrestrial magnetism, the phenomena of atmospheric electricity depend vitally upon the processes of ionization and dis-

tribution of electric charge in these lower regions. Special observations and studies of formation, mobility, and abundance of various classes of ions and their interrelationships at Washington clearly demonstrate the presence of ions which move in an electric field with velocities between those of the well-known slow- and fast-moving ions, and indicate that both the abundance and mobility of these intermediate ions vary throughout the 24 hours. Opportunity to measure the electric conductivity of the air up to an altitude of 22 km (14 miles) was supplied by the flight of the National Geographic Society—Army Air Corps stratosphere balloon, *Explorer II*, which carried the necessary recording apparatus designed and constructed at the Department. The principal deductions resulting from this flight are: (1) The upper regions of the atmosphere are at 400,000 volts higher potential than the Earth; (2) the conductivity at 60,000 feet is about 100 times as great as at the Earth's surface; and (3) the previously accepted relationship between air-pressure and recombination of ions does not hold.

Since studies in terrestrial magnetism and electricity must be approached frequently from a statistical point of view, investigations in mathematical statistics were actively continued. Particular attention was devoted to deriving simplified methods adequate to correctly develop the morphology of time-curves describing cyclic and periodic phenomena, as compared with random fluctuations. Too frequently the treatment of cyclic phenomena by various methods disregarding the theory of mathematical probabilities has hindered and even masked proper interpretation or physical significance. Application of researches conducted at the Department during recent years are being made in other fields where the powerful methods of statistical analysis are of first importance, for example, in other branches of geophysics and in biology.

## INVESTIGATIONAL AND EXPERIMENTAL WORK

### TERRESTRIAL MAGNETISM

Most of the theoretical investigations in terrestrial magnetism during the report-year related to the various aspects of those somewhat irregular fluctuations known as magnetic disturbances. Current-systems which would give rise to the fields of magnetic storms were constructed by both approximate and formal analyses; there was striking agreement of the results from the two methods. Those short-time fluctuations which are designated as magnetic bays received considerable attention and their perturbation-fields were mapped; a theory of these bay-disturbances was formulated, the tenability of which must yet be investigated. Good progress was made in the development of rational methods for the mathematical treatment and analysis of data for the determination and interpretation of cycles and periodicities.

Discussions of associated observations of auroral and magnetic conditions in high latitudes furnished a better understanding of the relations between these phenomena. Although magnetic disturbances are conspicuous in their irregularity, they exhibit certain characteristics which are remark-

ably consistent, so that the explanation of isolated manifestations may furnish a general concept of all disturbances.

Consideration of the regular diurnal-variations has not been neglected. Some evidence from the ionospheric studies was adduced for the support of the dynamo-theory at the expense of other theories. Attention was given the possibility of attacking some of the problems of terrestrial magnetism by experiments in the laboratory, and definite ideas toward this end have been outlined.

Besides their own immediate share in the results of investigations of terrestrial magnetism which are briefly indicated below, Dr. J. Bartels and Professor S. Chapman, research associates of the Institution, have made constructive suggestions most helpful in the details of the Department's program. Those of the regular personnel who have had the responsibility of the various researches reported upon include Berkner, Davies, Ennis, Fleming, Forbush, Johnson, Johnston, and McNish. Some share was also taken in the investigations by Dr. C. T. Kwei of Central China College and by Professor L. Slaucitajs of the University of Riga as guests at the Department engaged in the study of the methods and technique followed in its program.

#### STATISTICAL INVESTIGATIONS

*Cycles and periodicities*—In a series of conferences held in August 1935 at the Institution's Laboratory of Plant Biology, at Mount Wilson Observatory, at the University of Arizona, and at the Institution's Alpine Laboratory, the question of cycles and of periodicities and their treatment were discussed (see p. 41 of President Merriam's Report, Year Book No. 34). Dr. A. E. Douglass, Dr. Dinsmore Alter, and Dr. Frederic E. Clements demonstrated their methods for studying the involved questions of climatic cycles. Various aspects were discussed as follows: Biological, by I. W. Bailey and Dr. R. W. Chaney; physical and astrophysical, by Dr. Walter S. Adams, Dr. F. H. Seares, Dr. Seth B. Nicholson, and Dr. F. E. Wright. The Department, represented by J. Bartels and S. Chapman, contributed the experience gained in its extensive study of geophysical cycles of which the following standard types of cycles are most clearly shown: Persistence in the solar and lunar-diurnal variations of terrestrial magnetism; persistence in the semiannual wave of magnetic activity; quasi-persistence of the 27-day tendency in recurrence of magnetic disturbance due to the Sun's rotation. It was agreed that the analytical, graphical, optical, or mechanical procedures used in one method could be interpreted in the terms appropriate to the other methods.

Inadequate application of mathematical methods, especially of harmonic analysis, seems to have made some investigators with non-mathematical training suspicious not only of the results of such faulty applications but in general of mathematical methods beyond those elementary ones of averaging, smoothing, etc. This attitude has been to some extent justified in so far as the analytical approach had not been combined with the methods of general statistics and theory of probability. The indicated lack of aid offered so far by applied mathematics to research on cycles has already been partly remedied, and makes it desirable to intensify studies on what

may be called the mathematical analysis of the morphology of time-curves describing biological, geophysical, and cosmical phenomena, as compared with random fluctuations in their varying forms of appearance.

Such studies should preferably be "intensive" in character, that is, confined at first to the detailed analysis of a few long series for each type of data—for example, tree-rings, rainfall, and other climatic elements—and their interrelations. Only when adequate methods have been developed in a manageable form for expressing the peculiarities of such time-curves will there be a firm basis on which more or less generally recognized results on cycles can be expected, instead of the present bewildering variety of cycles and views on cycles offered. Until some progress has been achieved on such "intensive" studies, it may be doubted whether it is wise to plan an extensive attack on cycle-problems, applying relatively unrefined methods to very large masses of data.

The statistical properties of certain types of series such as are encountered in time-series of geophysical, economic, and similar variables were studied. Defining a correlative series as a series in which the  $n$ th term is given by  $a_n = (ra_{n-1} + e)$ , where  $r$  is a correlation-coefficient,  $e$  is a random quantity, and the values of  $a$  are measured as departures from a mean for the whole series, it can be shown that the precision-modulus for the distribution of cosine- and sine-terms derived from the series is not connected with the precision-modulus for the distribution of the values of  $a$  by the same relation as if the series were composed of purely random quantities. The precision-modulus of the trigonometric terms in a correlative series is a function of  $r$ , the "wave-length"  $\lambda$  of the terms, and the standard deviation  $\sigma$  of the values of  $a$ . For a given value of  $\lambda$  the ratio of the precision-modulus of the trigonometric terms to the precision-modulus of the values of  $a$  varies from unity for very small values of  $r$ , rises to a maximum as  $r$  increases, and then falls to zero for very large values of  $r$ .

This property of a correlative series causes it to manifest "cyclic" characteristics, and gives rise to many of the "cycles" found in series of geophysical and similar variables. The distinction between "cycles" arising from such a cause and those which depend upon some underlying truly periodic phenomenon is that in the former case no prognostication can be made regarding the reappearance of any particular cycle in the future. The application of these formulæ to the cycles found in many meteorological variables was discussed in a paper reported before the Section of Meteorology at the Seventeenth Annual Meeting of the American Geophysical Union.

#### ISOMAGNETIC CHARTS

*Eccentric dipole*—It is an elementary fact that the permanent magnetic field of the Earth, regarded as a whole, resembles the familiar field of a short bar-magnet (equivalent magnetic dipole or doublet) situated at the Earth's geometric center with an axis about  $11^{\circ}5'$  oblique to the axis of rotation. For some problems involving the effect of the magnet Earth on various phenomena, the degree of approximation furnished by this idealized picture (or its equivalents, for instance, a homogeneous magnetization throughout the sphere, or a suitable distribution of currents) is satisfactory.

There are, however, notable exceptions. In connection with the theory that highly penetrating corpuscles deflected by the Earth's magnetic field are the primary cosmic radiation, the asymmetry found in the intensity-distribution of this radiation around the Earth's equator must be related to a similar feature in the magnetic field; in fact, the horizontal component of the Earth's field varies on the magnetic equator from 0.40 Gauss in Siam to 0.28 Gauss in South America. A convenient mathematical representation of this asymmetry in the Earth's magnetic field was indicated by Adolf Schmidt. It consists in shifting the equivalent dipole from the geometric center to the magnetic center, 342 km toward a point on the surface in latitude 6°5' north and longitude 161°8' east. In view of the many uses which this "eccentric dipole" might have in cases in which the Earth's magnetic field is considered as a whole, its field was computed by Bartels, Chapman, and Schneider and communicated in extensive tables and charts.

The improvement in the approximation to the actual field afforded by the eccentric dipole, as compared with the usual approximation afforded by the centered dipole, is hardly noticeable for the Northern Hemisphere but quite distinct in the equatorial region and in the Southern Hemisphere. The differences between the actually observed magnetic field (for the epoch 1922) and that of the eccentric dipole are of special interest as regional anomalies indicating the effect of the Earth's outer crust.

*Geomagnetic coordinates*—Charts giving the geomagnetic coordinates—that is, latitude, longitude, and direction referred to the geomagnetic pole—for the entire Earth and nomographs for obtaining the geomagnetic coordinates quickly and accurately for any given point were completed and published. Geomagnetic coordinates may be read directly from the chart, with an accuracy of nearly 1° by interpolation, while the nomographs permit coordinates to be determined accurately to 0°1'. These charts and nomographs effectively supply investigators engaged in related researches—for example, distribution of cosmic rays—in that they eliminate the lengthy process of exact calculation of geomagnetic coordinates. A close dependence of many magnetic phenomena on the geomagnetic coordinates is becoming increasingly evident and motivated the International Union of Geodesy and Geophysics to pass at its triennial meeting in 1933 a resolution urging the construction of geomagnetic charts.

#### MAGNETIC DISTURBANCES

*The field of world-wide magnetic storms*—The external current-systems giving rise to the local-time and storm-time components of magnetic storms were constructed by Chapman, while at Washington, using a new approximate method based on the assumption that a certain portion of the observed magnetic field at all places is due to external causes. The current-systems are believed to flow in the upper regions of the atmosphere from certain *a priori* considerations. The total current flowing around the Earth between the north and south poles on days of moderate disturbance is estimated to be 750,000 amperes. The possibility that the currents may not flow wholly in the Earth's atmosphere is discussed and rejected, though not conclusively, in favor of the atmospheric origin.

The field of magnetic storms which is independent of local time was studied by comparison of the vector-differences of the magnetic field on disturbed and quiet days at 19 widely distributed observatories during the magnetically active year 1927. The data, ordered according to the geomagnetic coordinate-system, were fitted by the first four zonal harmonics of odd degree. So closely did the directions of the vectors correspond to the geomagnetic directions that it was not deemed necessary to use harmonics involving longitude-terms. Coefficients determined separately from the horizontal and vertical components of intensity permitted a separation of the field into those portions due to internal and to external portions. The ratios of the coefficients for the several internal and external harmonics indicate that the internal portion is not a result of simple induction, but is complicated by other factors—perhaps the non-homogeneous conductivity of the Earth due to oceanic areas or to a complicated mode of variation of the external harmonics, such as might arise due to a shifting of the auroral zone in storms of greater or lesser intensity.

Assuming that the magnetic effects were due to electric currents flowing in spherical shells concentric with the Earth, current-systems were constructed to represent the variations. The external current-system was found to have three regions of maximal density—one at the geomagnetic equator and the other two about  $20^\circ$  from each of the geomagnetic poles. Similar maxima were found for the internal system also, the poleward maxima being closer to the geomagnetic equator.

*Bays*—An investigation of short-time magnetic disturbances called bays was undertaken, using data from the observatories of the Department and of the United States Coast and Geodetic Survey, together with the data from the temporary observatories established by those and other organizations in the program of the Second International Polar Year. These bays, ordinarily of about one hour's duration, are found to be manifested simultaneously practically all over the Earth. The disturbances in polar regions are much more irregular than in lower latitudes, and their amplitudes there are about ten times greater.

By representing each bay at each observatory by one or several vectors, the distribution of their magnetic fields over the entire Earth can be fairly well apprehended. The magnetic fields are such as would be due to an intense westward current along the auroral zone, with a maximum near the midnight meridian, accompanied by the currents over the remaining portions of the Earth necessary to satisfy the conditions of continuity of flow. The general circulation closely resembles the form of the current-system deduced for the magnetic diurnal-variation on disturbed days. Attributing the effects to plane current-sheets overhead at the various observatories, a westward current-density of about 1000 amperes flowing between circles of latitude one kilometer apart is indicated. Data so far available from the Southern Hemisphere indicate that the phenomenon in that hemisphere is a mirror-image of that in the Northern, westward currents corresponding to westward currents in both hemispheres, while the northward and southward currents are reversed.

The hypothesis was advanced that these bays are caused by electric currents induced by the motion of the air in auroral regions, heated by the incoming radiation which produces the auroral display. Associated currents in lower latitudes arise through the necessary condition of continuity of electric flow.

*Pulsations*—Open time-scale magnetograms secured at the Watheroo Magnetic Observatory during 1933 furnish excellent resolution of pulsations of periods from 20 to 80 seconds. The equinoxes were found to be most favorable for their appearance, the winter season less favorable, and the summer season least favorable. The predominance of the equinoxes was most marked for pulsations with periods of 20 to 30 seconds. These short-period pulsations appeared most often on days of average international magnetic character-number 0.8 to 1.5. The recurrence of the short-period pulsations after a 27-day interval was quite evident; out of 69 days on which they appeared, 53 were recurrences, there being six such recurrences for one particular series.

*Non-cyclic change*—The change in direction and intensity of the Earth's magnetization at the observatories of the Department and of the United States Coast and Geodetic Survey on internationally selected quiet and disturbed days—that is, days notable for the absence or presence of irregular fluctuations—was investigated as one aspect of magnetic disturbance. The horizontal component of magnetization at all observatories increases on quiet days and decreases on disturbed days, while the vertical component decreases on quiet days and increases on disturbed days. These changes are a function of geomagnetic latitude, representable by the first-degree zonal harmonic about the Earth's axis of uniform magnetization. The portions of the non-cyclic change due to causes within and outside of the Earth were separated by harmonic analysis for the international quiet days and international disturbed days of 1923 and 1926. The ratios of the internal harmonics to the external harmonics for all four cases lay between  $1/4$  and  $2/5$ , in fairly close agreement with the corresponding ratio for the internal and external harmonics of the diurnal variation, which is  $2/5$ . The non-cyclic change on disturbed days may be attributed to an increasing westward current encircling the Earth's magnetic axis with density proportional to the cosine of the geomagnetic latitude and an accompanying internal current induced by it preventing a portion of the magnetic flux of the external current from entering the Earth, while that on the quiet days may be attributed to the decay of this current and the induction of a corresponding current within the Earth to sustain the field. The amount of non-cyclic change in horizontal intensity at the Watheroo Observatory during 1919-34 agrees with the yearly and seasonal distributions of world-wide magnetic activity, for both quiet and disturbed days.

*Auroral relations*—Investigation of the observational data obtained by the first Byrd Antarctic Expedition for correlation of auroral intensity with magnetic conditions represented by values of horizontal intensity was made. The "disturbing force" (amount and direction) was computed for each half-hour during the day for June, July and August from "normal-day" departures of observed values of declination and horizontal intensity. The

results, classified according to the presence or absence of auroræ, show interesting contrasts and similarities with respect to the two classes. Of special note is an outstanding post-midnight maximum in the disturbing force, occurring consistently, from the standpoints of time and magnitude, but only when auroræ were present and at a time of day when auroral intensity was at about its daily minimum. Another feature revealed by vector-diagrams of the disturbing force is the two-loop, day and night characteristic.

High correlation between magnetic and auroral activity was found for the Polar Year station of 1932-33 at Chesterfield Inlet, using data for September 1932 to April 1933. A comparison, suggested by Chapman, of magnetic and auroral activity for different parts of the night showed high correlation-values for the 9-hour period from 18<sup>h</sup> to 3<sup>h</sup> local time, but markedly weaker correlation for the morning hours 3<sup>h</sup> to 6<sup>h</sup>. Both auroral and magnetic activity diminished during the morning hours, but the latter decreased the more rapidly. The morning hours were differentiated from the night hours in respect to the direction of auroral arcs and bands. A change from the northwest to southeast direction, common to night hours, to a southwest to northeast direction during the morning hours, very often occurred, following a temporary lull in auroral activity.

#### MAGNETIC DIURNAL-VARIATIONS

*Tests of theories*—The results of the analysis of the magnetic diurnal-variations in the Western Hemisphere, completed during the preceding report-year, were studied with regard to their bearing on the several theories of diurnal variation. The evidence strongly indicates that the anomaly of the Western Hemisphere may be explained only on the basis of the dynamo-theory proposed by Balfour Stewart. The variations indicate the presence of such effects as might arise through the presence of zonal harmonics which vary in intensity with the time at some fixed meridian. These zonal harmonics were predicted in accord with the theory by Schuster, who first considered the effect of the obliquity of the Earth's magnetic axis with respect to its rotational axis.

The interpretation of radio observations is also favorable to the dynamo-theory. Reflection and penetration of the lower or *E*-region of the ionosphere occurring for the same frequency simultaneously indicate that collision-frequency there is high and consequently the direct-current conductivity perpendicular to the Earth's magnetic field required for the dynamo-theory may be considerable, particularly as the ion-density may exceed the electron-density by several orders of magnitude. The discovery from the ionospheric measurements at Huancayo and at Watheroo that the maximal ion-density of the *F*<sub>2</sub>-region does not undergo a simple seasonal variation, but rather an annual one, suggests that the total ionization may undergo a similar variation, thus opening a new line for investigating diurnal-variation theories. Since both the drift-current and diamagnetic effects must occur principally in those upper regions, an annual rather than a seasonal variation would thus be expected in the magnetic diurnal-variations if they are caused by diamagnetism or drift-currents, which is contrary to the observed facts.



Also, the greatest maximal ion-density of the  $F_2$ -region occurs in the afternoon or evening, which, if representative of greatest total ionization, calls for a maximum in the magnetic diurnal-variations in the afternoon or evening in accord with the drift-current or diamagnetic theory, thus introducing a greater phase-discrepancy for both of these theories.

*Lunar variation*—O. Schneider completed a thesis for his degree of Doctor of Philosophy on solar influences on the lunar variation of terrestrial magnetism, based on data for Huancayo and Batavia. One of the main conclusions is the recognition of a high degree of quasi-persistence; consecutive quiet days have diurnal variations which differ systematically from the variation normal for season and activity. This means in effect a reduction of the number of days available for computing average diurnal variations; thus the accuracy of average lunar variations compiled from, say, 1000 consecutive days, is not greater than that of about 400 individual days without quasi-persistence.

#### MAGNETIC ACTIVITY

*Character-figures and  $u$ -measure*—The data on magnetic activity for the year 1930 had shown a puzzling discrepancy between two measures of magnetic disturbance. Thus, according to the international magnetic character-figures ( $C$ ), the year appeared highly disturbed, while the  $u$ -measure indicated it to be little disturbed. In a discussion initiated by Dr. G. van Dijk of De Bilt, Bartels concluded that these contradictory results are not due to inherent faults of either measure, but to a characteristic difference in the conceptions of magnetic activity underlying both measures. This difference is one of gradation:  $C$  is high for 1930, because of the conspicuous absence of really quiet days and the predominance of a moderate degree of disturbance;  $u$  is low for 1930 because there were no great magnetic storms in that year. Which of the two measures fits better in a special case depends, therefore, on the sensitivity of the phenomenon considered to magnetic disturbance; according to data discussed by Dr. Austin Bailey, trans-Atlantic long-wave radio transmission is influenced by slight magnetic disturbance and therefore may be considered most profitably by using the international magnetic character-numbers.

*Polar-year records*—The tabulations of hourly values of declination and horizontal and vertical components of intensity for the two Polar Year stations at Point Barrow, Alaska, and Chesterfield Inlet, Canada, were completed. Hourly ranges of declination, horizontal intensity, and vertical intensity were tabulated for the Chesterfield station and daily values of the numerical magnetic characters were calculated as requested by the Polar Year Commission.

The magnetic elements at Point Barrow and Chesterfield Inlet during 1932-33 were very disturbed, even though the period considered was one of the quietest on record as far as solar activity is concerned. On the basis of magnetic activity, expressed by  $(HR_H + ZR_Z) 10^{-4}$ , these were among the most disturbed of all the Polar Year stations. Comparable values of mean annual activity, on this basis, are: Point Barrow, Alaska,  $3274 \times 10^{-4}$ ; Fort Rae, Canada,  $3088 \times 10^{-4}$ ; Chesterfield Inlet, Canada,  $2496 \times 10^{-4}$ ;

and Godhavn, Greenland,  $2070 \times 10^{-4}$ . In contrast, the mean annual value of the moderate-latitude station, Cheltenham, is  $248 \times 10^{-4}$ , approximately only one-tenth as much.

#### INSTRUMENTAL DEVELOPMENTS

*Electromagnetic methods*—It is the purpose of the Department's research on electromagnetic methods to develop a universal type of magnetometer for rapid and accurate absolute measurement of all components of the Earth's magnetic field. Following experimental and theoretical work, the alternating-current method of detection was applied successfully to the earth-inductor design of a universal magnetometer.

It was shown that the sensitivity of the earth-inductor may be increased many fold by using an alternating-current amplifier as a detector instead of a commutator and galvanometer. The CIW marine earth-inductor was modified for use with such an amplifier and it was shown that the accuracy was limited by the circle in measuring both declination and inclination. Determinations by this apparatus can be made with considerably greater rapidity than with the older method. Experimental records showed the continuously rotating coil of the earth-inductor may be used simultaneously as a declinometer and inclinometer.

An important application of the method lies in accurate measurements of dip and declination at sea. By recording the output of the earth-inductor with an oscillograph and comparing the time of zero-output with the angular coordinates of the base of the inductor, which may also be recorded by a damped pendulum, both declination and inclination may be determined with great accuracy.

These theoretical and experimental studies and those of standard cells and current-supplies resulted in the practical design of a portable field-magnetometer suitable for measuring  $H$ ,  $Z$ ,  $F$ ,  $D$ , and  $I$ , and which may also be used as a variometer for  $H$  and  $Z$ . Appurtenances of especial interest are a current-control to automatically maintain a current constant to one part in 100,000, an astatic galvanometer of medium sensitivity with the ruggedness of laboratory panel-meters, a carrying case for standard cells insulated against temperature and mechanical shock in which the cells can not be inverted, and a high gain amplifier of small dimensions.

The design of a new primary standard for  $H$ ,  $Z$ ,  $F$ ,  $D$ , and  $I$  has also been carried out which will have an absolute accuracy of approximately one part in 100,000. The standard coil form, already on hand, is of Pyrex with the recently developed low coefficient of thermal expansion.

An astatic magnetometer was designed and constructed for selecting non-magnetic materials for instruments—a first-order requirement and often overlooked by manufacturers. Its sensitivity of  $0.1 \gamma$  per mm of deflection is unaffected by the Earth's magnetic field and thus it may be conveniently used in any magnetically disturbed location, such as an instrument shop. Rapid and certain selection may be made of materials free from any magnetic effects to a few parts in 1,000,000.

CIW sine-galvanometer 1 was placed in permanent operation at the Cheltenham Magnetic Observatory for absolute measurements and control

of standards. Current-measurement and observational procedure were arranged so that a complete determination of horizontal intensity may be made by a single observer. From a long series of observations the observational error was shown to be approximately one part in 100,000 and it is believed the absolute accuracy is within a few parts in 100,000.

Attention was given the technique of low-voltage alternating-current measurements which show promise of useful application to other problems of the Department. Among these are (1) absolute measurement of earth-currents, (2) determination of magnetic gradients, and (3) measurement of pulses from ionization-chambers in nuclear investigations.

*CIW induction-variometer*—The induction-variometer (see last year's report) to record variations in the vertical magnetic-intensity component was further improved as the result of experience gained in its continued operation through the report-year and tests at the Cheltenham Observatory of the United States Coast and Geodetic Survey. Its performance fulfilled its purpose; it recorded satisfactorily over a large range of sensitivities considerably exceeding that required in practise. The instrument may be so adjusted that its temperature-coefficient is negligibly small. One notable feature is its constancy of performance with time. The first instrument was highly sensitive to changes in pier-tilt. While for well-built piers, sufficiently guarded against such effects as shift by frost, contact with floor, etc., this is perhaps negligible, the effect was minimized by incorporating a shorter suspension for the induction system; with this modification the sensitivity to tilt became inappreciable. The extensive tests clearly demonstrate the practicability of this instrument. Replacement by it of the balance-type of variometer is warranted, especially in view of the mechanical difficulties inherent in the design of the latter.

Other applications than for recording at observatories were proved feasible by proper modifications. Thus, it may be adopted (1) to measure horizontal-intensity avoiding certain faults in instruments used at present, (2) to measure, as a local field-variometer, anomalies in the Earth's vertical intensity, (3) to secure intercomparisons between standards at observatories and in the field, and (4) to serve as a null detector in a vertical-intensity absolute magnetometer.

## TERRESTRIAL ELECTRICITY

From the known phenomena of terrestrial magnetism the induction of electric currents in the Earth and a flow of electricity between the Earth and the atmosphere may be inferred. One attempt to explain the main part of the Earth's magnetic field assumes the existence of electric currents in the Earth; such currents should be steady in both direction and magnitude, and should be much more intense than those which it is expected would result from the changes of the magnetic field. Another outlook would have the steady part of both the magnetic and electric fields of the Earth result from a common cause.

Although the electrical phenomena of the Earth deserve study in their own right, the study of those electrical phenomena of the Earth, which have

a possible bearing on terrestrial magnetism, is especially appropriate for an institution dedicated to research on this subject.

These electrical phenomena naturally fall into two groups. In one group, *atmospheric electricity*, the lower atmosphere plays a conspicuous rôle; in the other, which includes electric currents in the Earth's crust, or *earth-currents*, the phenomena seem to be independent of conditions in the lower atmosphere.

Atmospheric electricity and earth-currents comprehend the subject-matter with which the Section of Terrestrial Electricity of the Department is concerned. During the report-year those engaged in the investigation of these subjects were: Atmospheric electricity, Gish, Forbush, McNish, Sherman, and Wait; earth-currents, Gish and Rooney.

#### ATMOSPHERIC ELECTRICITY

Observations of the electric field about the Earth and the electric current from the air to the Earth have thus far revealed no definite correspondence either with features of earth-currents or with those of terrestrial magnetism. In one respect the atmospheric-electric data and the magnetic data disagree—the electric currents flowing from Earth to atmosphere indicated by the magnetic measurements are about 10,000 times those revealed by atmospheric-electric measurements. This and other less startling negative conclusions which have resulted from a comparative study of terrestrial magnetism and atmospheric electricity are important for the implications they suggest.

Similarly, as in terrestrial magnetism, the most outstanding problem concerns the establishment and maintenance of the electric field or, what is the same thing, of the negative charge of the Earth. The key to the solution of these problems may be hidden deep in the foundations of physics. However, before adopting this view, it seems desirable in the case of atmospheric electricity that (a) a more complete record of the facts for the Earth as a whole be obtained, and (b) a better understanding be sought of how, under the influence of auxiliary factors, the observed facts are given local color.

The first of these is being met by the continuous registration of the air-potentials and of the two components (positive and negative) of air-conductivity, as well as of the principal meteorological elements, at the Observatories. The second was furthered during the current year by studies made by Wait at Washington of some of the factors affecting air-conductivity. Work contributing to both was done by Gish and Sherman in connection with the National Geographic Society-Army Air Corps stratosphere flight.

*Factors which influence air-conductivity*—A comprehensive understanding of the electric conductivity of the atmosphere is important to the investigation of the electric phenomena of the Earth because, in conjunction with the Earth's electric field, it controls the electric current flowing to or from the Earth's surface. Gases conduct electricity through the action of ions—molecules or aggregates of molecules of the gas which carry discrete electric charges. Impelled by an electric field, these ions are set into orderly motion and convey their electric charges from one place to another, thus producing

an electric current. The ions of the atmosphere are regulated by many complex phenomena. The ions are of various sizes and consequently have various velocities, while interactions between them affect their abundance. The smaller and faster ions are most effective in conducting electric current, but the larger and slower ions play an important rôle in combining with the smaller ions and so removing them from circulation. The small-ion supply is maintained by cosmic rays and radioactive substances which continually form new ones. Thus a comprehensive investigation of the electric conductivity of the atmosphere entails studies of the abundance, properties, rate of production and the interrelationships between the various classes of ions.

Continuous registration of the abundance of the various classes of ions in the atmosphere—those which move at high, medium, and low velocities under the action of an electric field—was conducted by Wait. These observations, supplemented by continuous registration of the rate of formation of the fast ions using a thin-walled ionization-chamber constructed by Wait and McNish, furnished a basis for a better understanding of the processes regulating the electric conductivity of the lower atmosphere. Automatic variation of the voltage of the ion-counters on alternate hours permitted the separate measurement of the fast and intermediate ions of either sign and furnished evidence from which their mobilities were deduced.

Many investigators have doubted the existence of ions of intermediate mobilities. Observations at the Department clearly establish their existence and show that they vary in mobility and abundance throughout the day. During certain seasons the abundance of intermediate ions varies as the abundance of slow ions, while at other seasons the relationship is reversed. When the two abundance-variations are opposite, the mobility of the intermediate ions varies as the number of slow ions present.

The abundance of small ions through the day has been compared with their rate of formation, as indicated by the ionization-chamber and the abundance of slow ions which play an important part in their removal. A value of the coefficient of their destruction thus deduced appears to be greater than that derived from theoretical considerations. Positive ions are more abundant than the negative ions in all three classes, although the abundance-ratios are not constant throughout the day.

Heavy and persistent snowfalls during the past winter permitted observations on the effect of a snow-blanket on the rate of formation of fast ions. Presence of a snow-blanket on the ground causes a marked decrease in the rate of fast-ion formation. Similar effects appear to obtain after a rain. This is believed due to the depletion of radium emanation and its decay-products in the atmosphere to which the fast ions are due, the snow-blanket and the damp soil restraining the escape of the emanation from the ground which is its original source.

*Registration of potential gradient and air-conductivity near Rapid City, South Dakota*—During preparations in the field for the flight of *Explorer II*, air-potential and air-conductivity were recorded on the rim of the natural bowl in which the balloon was to be inflated—about 15 miles south and west of Rapid City, South Dakota. Two different seasons of the year are rep-

resented in the data obtained. Of daily records in potential gradient meeting requirements for study, there were 16 during June to July and 24 during September to November. Compilations of data on these days gave mean values for atmospheric potential-gradient of 80 volts per meter and 69 volts per meter, respectively. Records of conductivity suitable for analysis for the days on which potential records were selected totaled 12 during June to July and 16 during September to November. The mean values compiled for the June-July and for the September-November groups were: Positive conductivity, 3.09 and  $3.44 \times 10^{-4}$  electrostatic unit, respectively; negative conductivity, 2.43 and  $3.14 \times 10^{-4}$  electrostatic unit, respectively.

The nature of the diurnal variation in potential gradient at this station agrees closely with that observed at sea on the *Carnegie* and is thus apparently of universal character. The diurnal variation in the total conductivity is approximately the inverse of that in potential gradient. The air-earth current—the product of potential gradient and total air-conductivity—varies during the day in similar manner to that of the gradient, but with smaller amplitude.

*Air-conductivity in the troposphere and stratosphere*—Satisfactory registration of the electrical conductivity of air was made throughout the flight of *Explorer II* with apparatus designed and constructed at the Department and described in last year's report (see Year Book No. 34, p. 231). The air-conductivity in general increased with altitude; the highest value, recorded at an altitude of 18 kilometers (60,000 feet), was about 100 times the average value observed on the *Carnegie* at the surface of the sea. Values recorded on the ascent were generally less than those on the descent. This was probably because dust or other "polluting" substances given off by the balloon affected the "sample" of air on the ascent but not on the descent; when ascending, the gondola was entering air which had been adjacent to the balloon, whereas when descending the gondola was entering air in advance of the balloon.

Positive-ion conductivity was always less than negative-ion conductivity, except for one spurious set of values at the "top." Contrary to a commonly expressed view, the negative conductivity at the high levels—low pressures—did not increase relative to the positive conductivity. Thus, either the rapid increase of negative mobility deduced from experiments in the laboratory at low pressures is incorrect or else more water-vapor exists in the high atmosphere than is generally supposed since the abnormal increase of negative mobility is less marked when small quantities of water-vapor are present.

The potential difference (voltage) between the Earth and high atmosphere, based on the conductivity-data and on measurements of air-earth current made at the Earth's surface, is about 400,000 volts. Nearly half of this increase occurs in the first two kilometers above the Earth's surface.

Calculations of the conductivity from Regener's cosmic-ray data, using generally accepted relations, gave greater values than were observed, the discrepancy increasing with altitude. This and other circumstances led to the surmise that the recombination-coefficient for small ions varies, not as the first power of the pressure but more nearly as the one-half power, which

brings the observed and calculated values into better agreement throughout the 12 kilometers between altitudes 6 and 18 kilometers.

Lack of agreement in the lower atmosphere is caused by condensation-nuclei. The distribution of these is derived from the difference between calculated and observed conductivity. A similar interpretation of the data for altitudes from 18 to 22 kilometers would indicate that the air in this high stratum contains several thousand nuclei per cubic centimeter. This and the fact that mother-of-pearl clouds are frequently observed at this level lead one to infer that condensation-nuclei are not uncommon at such levels.

#### EARTH-CURRENTS

Most aspects of that group of terrestrial-electric phenomena which are designated by the term "earth-currents" show close correspondence with varying aspects of terrestrial magnetism. So-called earth-current storms occur whenever magnetic storms are in progress, the electric current waxing and waning in a manner frequently very similar to the change in the strength of the magnetic field. The regular change during the day in the magnetic and the electric intensities is also obviously related. A more exact knowledge of the nature of the relation between magnetic and electric phenomena should therefore further a better understanding of both phenomena.

Studies made during the report-year by Gish and Rooney—possible because the accumulation of earth-current data had become adequate in respect to both quantity and distribution—aid advance in this direction. Especially was the distribution improved by the concerted effort put forth during the Second International Polar Year by the United States Coast and Geodetic Survey, the University of Alaska, the Canadian Meteorological Service, the Bell Telephone System, and the Department. The Bell Telephone System obtained registrations on long-distance telephone-lines at a number of widely distributed points in the eastern half of the United States, in addition to the continuous registrations of earth-current potentials throughout the Polar Year at three American stations, namely, New York City, Houlton (Maine), and Wyanet (Illinois).

The observed earth-current intensity (gradients) were synthesized to yield a world view of such electrical circulations in the Earth as would be approximately consistent with the major aspects of the diurnal variation in earth-current intensity registered on so-called quiet days. Apparently electric currents circulate in the Earth's crust in a number of extensive eddies. Eight of these are located in the middle latitudes. Four in the Northern Hemisphere and four in the Southern Hemisphere form a symmetrical arrangement about the equator. The centers of these eddies, about equally spaced in longitude, lie near the tropics.

Four other eddies also appear in high northerly latitudes with their centers near the Arctic Circle, about equally spaced in longitude. A corresponding set of eddies presumably exists in high southerly latitudes, but data to establish the fact are not available.

All these eddies follow the Sun so that eight are always on the sunlit side of the Earth and eight on the dark side. The current in the daylight eddies

of middle latitudes is considerably greater than in the night-time eddies. The eddies in high latitudes, however, show no conspicuous contrast of this character. The centers of the eddies in middle latitudes lie near the meridian for which the times of day are 9 a. m. and 3 p. m., respectively. The circulation of current is clockwise in the forenoon eddy of the Northern Hemisphere, the sense of the circulation in the other middle-latitude eddies being such that the circulation is opposite in any two adjacent eddies of corresponding latitude.

The high-latitude eddies have circulations opposite to those of middle latitudes, there being an area between these eddies in which the currents (or impelling forces) of the two eddies are in conflict. The entire system of eddies moves with the Sun in its apparent daily motion so that a given place on the Earth will occupy different positions in the system of eddies at different times of day.

Because of the great contrasts in electrical conductivity presented by different constituents of the Earth's crust—especially that between sea-water and land, and because of the irregular distribution of these—considerable tolerance must be allowed in the simple picture which is here presented. The eddies must be regarded as very flexible and easily deformable, so that their content may vary, their shape may be distorted, and their progress around the Earth may be halting and devious. It seems likely that the development and orientation of the eddies is complicated by the fact that the magnetic axis of the Earth does not coincide with its geographic axis.

A study auxiliary to the above consisted in an attempt to construct the system of circulations which, if superposed on that corresponding to quiet days, would yield a current-system consistent with the observed characteristics of the diurnal variation in earth-current intensity and direction on disturbed days. This component of the disturbed-day circulations is simpler than the main component. Two eddies in a given middle-latitude belt are indicated instead of four, as was found for the main component in the study of the quiet-day diurnal-variation data. Longer series of data from a wider distribution of stations must be studied in order to clearly establish the character of this circulation, which may be regarded as the disturbance-component of the system.

The earth-current records for a number of years from Tucson, Huancayo, and Watheroo were examined by Rooney to determine if any constant component or long-period variation is detectable. Such determination is made difficult by masking effects of electrochemical potentials at the electrodes of the measuring system. The recorded daily mean values of potential on characteristically disturbed and calm days differ consistently by a small amount. This suggests that a part of the current flowing during disturbances or magnetic storms is unidirectional for the day and is the first definite indication of a component in earth-currents with period greater than one day. The effect, which may be regarded as the earth-current aspects of the world-wide component of magnetic storms, is small in magnitude, not more than a few per cent of the range of normal diurnal variation. The direction of flow appears to be toward the north and east at Tucson and to the south and east at Huancayo, but in both cases the direction may be modified by local



geological features. Comparatively large and irregular contact-potentials occurring at Watheroo cause results from that station to be inconclusive on this point. In so far as they have any significance, the results are in agreement as to direction and relative order of magnitude with those obtained at Huancayo. The reversal in direction of the northward component as the equator is crossed is also a feature of the diurnal-variation records at these and other stations. A more accurate quantitative measure of the effect is necessary before attempting to suggest a system of current-circulation consistent with the effect.

### INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO TERRESTRIAL MAGNETISM

The origin of short-time variations of the Earth's magnetic field in regions external to the Earth's crust is well established. Except in a most general way, however, the physical mechanisms which control these effects are not yet understood. Numerous theories have been advanced to explain the various phenomena, but the paucity of independent evidence does not yet permit a decision as to the predominating factors. Notwithstanding, a common basis for the various theories exists—each postulates an upper atmosphere containing electrically charged ions. Their essential differences depend upon the numbers, the physical nature, the distribution, and the motions of these ions in the Earth's outer atmosphere, and the changes in these factors with time.

The evidence for the existence of an electrified upper atmosphere, or "ionosphere," appears independently from study of the propagation of radio waves. Such investigations yield quantitative information concerning many of the physical features of the ionosphere, and, with the development of necessary experimental and theoretical tools, may be expected to give a picture of the upper atmosphere which is sufficiently comprehensive to more clearly define the essential physical mechanisms involved in terrestrial magnetic effects. While these methods are useful above about 80 km where the ions are abundant, other methods must be used at lower levels where the rate of recombination is extremely high, such studies falling under the head of terrestrial electricity.

In order that the problems of terrestrial magnetism might be vigorously attacked from this independent approach, this Department has pursued a program of ionospheric research by radio methods since its inception here by Breit and Tuve in 1925. The results have yielded data which are not only significant in the study of terrestrial magnetism, but are of great importance to the problems of radio transmission, changes in solar radiation, and in relation to many other physical phenomena.

Four essential types of investigation are involved in this study of the ionosphere. Special experiments are necessary to determine the nature and distribution in space of the ionosphere and the nature of its reaction on the exploring radio waves; continuous recording must provide a knowledge of the changes with time; the recorded data must be properly reduced for study and comparison with other phenomena so that basic relationships may be discovered and interpreted; technique and equipment must be devel-

oped for the conduct of the experimental observations and their interpretation. The last two types are investigated at Washington, through analysis of data, instrumental development, and training of personnel. Experimental work for the first two types is done at the Department's observatories in the field to furnish data for a world-wide picture of the ionosphere. Experiment, subsequently outlined, has shown essential differences in ionospheric structure peculiar to different localities, which are of primary importance in understanding the phenomena.

In reviewing the results of the program of ionospheric research during the report-year three major developments merit especial attention.

(1) Results of the program at the Huancayo and Watheroo magnetic observatories show that the maximum daily ion-density of the highest region of the ionosphere occurs in both the Northern and Southern hemispheres during the same time of year. What was thought originally to be a seasonal effect when viewed from the Northern Hemisphere alone is now proven to be predominantly a more complex annual one, probably changing everywhere over the Earth in much the same manner. This discovery renders untenable much hypothetical argument, especially concerning the temperature of the upper atmosphere which was based upon the assumption that the effect is a simple seasonal one, and emphasizes the necessity of world-wide observations on such a basis as will elucidate the essential facts.

(2) Special experiments conducted near the geomagnetic equator at the Huancayo Magnetic Observatory to determine the polarization of vertically downcoming radio waves show that such waves are plane-polarized in mutually perpendicular planes, as is predicted by theory. Thus strong confirmatory evidence is brought to support the theory in this important special case where the Earth's field is horizontal overhead. Under no other circumstances could plane polarization be observed.

(3) Development of the automatic multifrequency ionospheric recording-equipment was completed. This equipment provides for recording changes in the structure of the ionosphere with time at a particular station. It is the first equipment of its kind to operate over the necessary frequency-range continuously and automatically. It provides the basis for the future program of ionospheric recording at the observatories. The equipment was licensed for operation by the United States Government following an exhaustive series of tests during which it was demonstrated that operation does not interfere with other radio services, though they may be operating on the same frequencies.

To derive the greatest benefit from this program, a close relationship with other investigators in the field is imperative. The complexity of the problem precludes the possibility of a complete solution by a single group of investigators. Efforts are being directed toward standardized methods of exchange of data. The conferences on the ionosphere held at the Department in 1935 and 1936 have provided the initial steps in this direction, and a basis has been established for the extension of this exchange of information.

The program was carried on by Berkner at Washington, by Wells and Stanton at the Huancayo Magnetic Observatory until September 1935 when Wells returned to Washington to assist Berkner, Stanton continuing at

Huancayo, and by Seaton at the Watheroo Magnetic Observatory. Professor E. H. Bramhall of the University of Alaska and Professor C. T. Kwei of the Central China College each spent several months studying the technique of observation and conducting experimental measurements—the first to prepare for a similar program already begun in cooperation with the University of Alaska at College, Alaska, and the latter in expectation of establishing a similar research in China.

#### RESULTS

*Observations at the observatories*—The program at the Huancayo Magnetic Observatory involved manual multifrequency recordings for about 20 selected hours on Monday, Wednesday, and Friday of each week. During the remaining time continuous automatic recording was maintained on a frequency of 4.8 mc/sec. In addition special experiments on polarization were conducted.

A similar program of manual multifrequency measurements was conducted at the Watheroo Magnetic Observatory. These measurements involve observations of the virtual height of the ionization at small frequency-increments throughout a wide frequency-range. An irregular schedule of automatic multifrequency recording, which was largely in the nature of tests, was maintained at the Department's Experimental Station at Kensington, Maryland.

*Investigation of the  $F_2$ -region*—The observational series reveals that the lowest values of daily maximum ion-density of the  $F_2$ -region have occurred around the June solstice at Watheroo and Huancayo as well as at Washington. A secondary but less-defined minimum is also apparent at all stations around the December solstice. This variation, reported by Berkner, Wells, and Seaton, appears to be predominantly an annual effect occurring at all stations in much the same manner. This discovery makes necessary a reconsideration of the hypothesis of thermal expansion of the upper atmosphere which was based upon the assumption that the effect was a seasonal one, as appears when observed in one hemisphere alone. The apparently anomalous behavior of the  $F_2$ -region at Huancayo as reported last year foreshadowed this development.

In contrast, the variation of minimum virtual height of the  $F_2$ -region appears to be of a seasonal nature at all stations. At Huancayo the character of the seasonal variation is the inverse of that observed at Watheroo and Washington. This indicates a reversal of character in the equatorial zone, though information from but three stations seems inadequate as a basis for a definite opinion.

During the past year a very marked increase in the average maximal ion-density has taken place in the  $F_2$ -region. This increase (apparently somewhat over 50 per cent) is sufficient to have an important bearing upon terrestrial magnetism and radio transmission. The increase in solar activity during this period is particularly suggestive, and an extension of the series must yield definite information. Because of the lack of symmetry in distribution of the maximum ion-densities of the  $F_2$ -region over the Earth, average conditions of propagation of radio waves for this region in the Southern

Hemisphere should be somewhat superior to similar conditions in the Northern Hemisphere.

*Investigations of the E- and  $F_1$ -regions*—Continued observation confirmed the seasonal variations in virtual heights and maximum ion-densities previously reported. The separation of the  $F_1$ - and  $F_2$ -regions during daylight at a particular latitude is somewhat less marked than was previously the case. Likewise the average maximum ion-densities of these regions increased during the past year, though not in the same proportion as the increase observed in the  $F_2$ -region.

*Special experiments*—Experiments were conducted at the Huancayo Magnetic Observatory to determine the polarization of vertically downcoming radio waves at the geomagnetic equator. The theory of wave-propagation in the ionosphere predicts that in this special case the waves should be plane-polarized in two mutually perpendicular planes. The measurements reported by Wells and Berkner confirm this polarization for waves returned from the  $F$ -regions. Previous quantitative confirmation of the theory has proven difficult because of the elliptical polarization observed in all other geomagnetic latitudes. The experiments therefore furnish strong evidence confirming the accepted theory of wave-propagation through the ionosphere upon which deductions of ion-density are based.

*Sporadic ionization of the E-region*—Continuous records at Huancayo show that sporadic ionizations of the  $E$ -region seldom occur there and only then of small intensity. Such events occur frequently, however, at Washington and Watheroo, and even more frequently at College, Alaska. These facts suggest a frequency-distribution with latitude of much the same nature as certain magnetic disturbances, such as bays, and open a particularly inviting field of investigation.

*Reduction and analysis of data*—Reduction of data for hourly values of minimum virtual height, character, and critical frequency of each region was kept current. Analysis of the  $F$ - and  $F_2$ -regions was completed to date and published. Analysis of the  $E$ - and  $F_1$ -regions was begun. A simplified method of reduction and analysis was adopted on the basis of accumulated experience, which shortens the time required in reduction and permits a more detailed analysis of the data.

*Cooperative endeavor*—The cooperative schedule of observations with the National Bureau of Standards was continued during the year. This provides for simultaneous observations at Huancayo, Washington, and Watheroo. Further exchange of data was arranged.

The second Conference on Ionospheric Measurements was held at the Department on May 1, 1936. It was attended by representatives of laboratories, educational institutions, and communications organizations whose activities relate to ionospheric research. Subjects considered were: (1) Measurements of magnetic activity for correlation with radio data; (2) desirability and methods for more complete exchange of radio data; (3) relations between ionospheric and various extra-terrestrial phenomena; and (4) recent developments in ionospheric investigations. The opportunity afforded by these conferences provides a stimulus for cooperative endeavor in this field.

In order that the contribution of ionospheric research to studies of terrestrial magnetism might be most fully appreciated and utilized, a seminar on upper atmospheric investigation was conducted at the Department each Monday evening. Three general phases of the work were considered, as follows: (1) Experimental technique of upper atmospheric investigation; (2) basic mechanics of wave-propagation through the ionosphere as an inhomogeneous, anisotropic medium; and (3) results of modern ionospheric research.

Active cooperation was maintained with President C. E. Bunnell and Professor of Physics E. H. Bramhall of the University of Alaska in the design and installation of equipment for manual multifrequency measurements in the polar region at College, Alaska.

#### INSTRUMENTAL DEVELOPMENT

*Automatic equipment*—Development of the automatic, multifrequency recording-equipment was completed. It is designed to provide the basis for the future ionospheric recording-program at the observatories. It permits continuous and automatic recording of the details of the ionosphere. The measurements are made through a frequency-range of 0.516 to 16.0 mc/sec, which provides for a sufficient range of penetration to delineate the whole structure of the ionosphere which can be observed by radio methods.

Inasmuch as transmissions in this band must be made in thousands of frequency-channels now occupied by other radio services, it was necessary to devise an equipment which would not interfere with these services, and at the same time provide satisfactory recording on the frequencies of these services. This feature was the subject of an exhaustive series of tests by engineers of the Federal Communications Commission, following which, license was granted the Department for unlimited operation at Kensington, Maryland, under the designation of Special Experimental Station, W3XFE.

Detailed attention has been given to the mechanical features in order that extended operation will be possible without difficulty. C. Huff, prior to his untimely death, and Steiner, his successor in the instrument-shop, cooperated closely in providing suitable mechanical designs.

*Testing*—As all experimental and testing work on the radio equipment must be conducted outside highly congested areas, much of the development was done at the Experimental Station near Kensington, Maryland. The area of some ten acres about that station was made available by the continued courtesy of Col. M. K. Barroll, U. S. A. (retired), who maintains an active interest in this work.

*Single-frequency recording equipment*—Equipment for automatic single-frequency recording at the Watheroo Magnetic Observatory was completed in the shop and tested, and is being installed at the Observatory to supplement the observational program as is done at Huancayo until the automatic multifrequency equipment is installed.

*Power-installations*—Additional power-facilities were installed at the Watheroo Magnetic Observatory to provide for continuous 110-volt alternating-current power-supply necessary for the operation of the ionospheric equipment. This installation is practically identical with that now in

operation at the Huancayo Magnetic Observatory, described in last year's report. The design of the automatic multifrequency equipment is such that less than one kilowatt is required for operation, while the peak-output during pulses is about 0.8 kilowatt.

*Development of technique*—Improved methods of introducing the power into the radiating systems were devised and adopted at the observatories. Practically constant radiated power at all frequencies is now maintained.

### MAGNETISM AND ATOMIC PHYSICS

An important new physical force, in its way as fundamental and significant as the force of gravitation or that of electric attraction and repulsion, was directly observed and measured for the first time in the Department's laboratory this year. This force is an attraction between the component primary particles, protons and neutrons, causing them to aggregate and form the central nuclei of all atoms; thus it underlies the existence and form of all larger things in the material universe. It has hitherto been inferred to exist, because atoms heavier than hydrogen are known. The truly basic physical forces are exceedingly few in number, and the initial observation and measurement of such a force is a correspondingly unusual event. It is worthy of emphasis that these measurements represent the attainment of one of the original objectives in a program of fundamental investigations begun ten years ago.

At that time the Department initiated a program of high-voltage researches looking toward ultimate studies of the forces and other interactions or relations between the component parts of atomic nuclei. This program was begun in the belief that such studies involve the simplest and most basic questions which it has seemed possible to frame with regard to the intrinsic nature of the forces or actions underlying the phenomena of magnetism. During this report-year one of the principal experiments described in the original statement of the project was carried out, namely, the study of the angular deflections of high-speed protons due to collisions with other protons, as a means of examining the law of interaction of two protons when brought near to each other. (Protons are the nuclei or "massive central cores" of ordinary hydrogen atoms, and form a principal constituent of every other atom in the universe.)

During the development of the high-voltage equipment and technique for these nuclear-physics investigations, rapid contemporary development of the "natural philosophy" branches of physics—which deal with the fundamental aspects of the nature and structure of matter—simultaneously made this earlier question regarding the forces of interaction between protons a key-problem. On it hinges much of the modern understanding of the basic forces which make inanimate Nature manifest in the laws of chemistry, electricity, and mechanics. One of the most puzzling difficulties in the understanding of atomic structure was resolved in 1932 with the discoveries of the neutron and the positive electron. These discoveries separated, in a sense, the "heaviness" aspect of matter from its electrical aspect. Thus instead of all matter being considered as made up solely of protons and negative electrons (and energy) as previously thought, it became clear that

two rather similar heavy units, protons and neutrons, form the massive nuclei of all atoms, the protons being electrically charged (positively). There exist as well two other units of small intrinsic mass, again similar to each other but both electrically charged, positive electrons, and the negative electrons which form the outer "shells" of all atoms; these latter units act as the chief connecting links between matter and energy in the form of electromagnetic radiation.

As a result of this clarification, the basic forces which bind together matter and energy to form atoms and then all larger material bodies are necessarily very few. They comprise the mutual interactions between protons and neutrons, the interactions between these units and electrons (positive and negative), and lastly the interactions of these several types of particles with energy in the form of radiation.

The Department's special contribution during this report-year has been the measurement of the proton-proton interaction, with some additional important evidence regarding the proton-neutron interaction. Interpreted jointly with other information and calculations it has developed that all of the three possible interactions between these two bodies, the proton-proton, neutron-neutron, and proton-neutron interactions, have been unambiguously determined by these experiments. Measurements made elsewhere on the scattering and absorption of slow neutrons and on the masses of light nuclei are similarly important, although by themselves such data were quite insufficient to determine the various interactions. From the analysis of these proton-scattering experiments, a remarkable new simplification of our knowledge of the nature of matter has emerged. Protons and neutrons, the two kinds of massive particles from which all matter is constructed, are shown by these studies to be probably identical in every respect except that of electrical charge. The only differences between the proton-proton interaction and the proton-neutron and neutron-neutron interactions are ascribable to the fact that a proton has the charge of one positive electron in addition to the other properties (mass, spin, magnetic moment, dimensions in space) which are possessed by a neutron.

Thus the Department's program, intentionally guided for ten years toward the specific goal of making measurements to elucidate these simplest questions which can be formulated with regard to the basic framework of the laws of matter, has uncovered a beautiful and simple fact of nature which is fundamental to all physical knowledge. Of course, these far-reaching conclusions must yet be confirmed by repetition and extension of the measurements, especially at higher voltages than are available with the Department's present equipment, but whatever may be the future modification, it appears clear that the contribution made here this year will remain of major importance in any interpretation which may ultimately be made.

#### THE SCATTERING OF PROTONS BY PROTONS

By experimentally measuring at different voltages the frequency with which high-speed protons from a well-defined beam are scattered through various angles as a result of single collisions with other relatively stationary protons in a given volume of hydrogen, a basis becomes available for impor-

tant deductions as to the forces of interaction which protons exert on each other when separated by various specific small distances, as mentioned above. The scattering to be expected on the basis of the familiar  $(1/r^2)$ -law of repulsion between like charges, assumed to hold even for minutely close distances of approach, was worked out by Rutherford and Darwin (1911-14) with the minor numerical modifications resulting from the quantum-mechanical identity of the two protons added later by Mott (1930).

Using the 1200-kilovolt electrostatic generator with the new high-resistance voltmeter and properly aligned tube described below, to produce a highly homogeneous proton-beam of the desired adjustable energy, counts were made (using a linear amplifier) of the number of protons scattered through various angles when passing through a path, about 2 mm long, of hydrogen at a pressure of 12 mm. For angles in the range measured ( $15^\circ$  to  $50^\circ$ ) plural scattering is negligible for this case, both experimentally and theoretically, and the observed particles are primary and recoil-particles which enter the particular angular region under observation as a result of single collisions. The measurements, carried out for voltages of 600, 700, 800, and 900 kilovolts, were made on an absolute basis, with an accurately defined scattering-volume and with an angular definition of about  $2^\circ$ . For angles of  $15^\circ$  and  $20^\circ$  the observed scattering at each voltage was about two-thirds of that predicted by Mott's formula, whereas at  $45^\circ$  the scattering varied progressively with voltage from somewhat under Mott's value at 600 kilovolts to four times Mott's value at 900 kilovolts. Intermediate angles showed correspondingly progressive changes.

Interpreted in terms of proton-proton interaction, these results show that at small distances, of the order of  $5 \times 10^{-13}$  cm or less, the ordinary inverse-square repulsion between like charges is overwhelmed by another proton-proton force, which is shown to be an attraction, according to the careful quantum-mechanical analysis of our measurements by Breit, assisted by Professor Condon of Princeton and Professor Present of Purdue. As mentioned above, these new attractive forces explain the aggregation of protons and neutrons into groups to form the nuclei of the various elements of the atomic table, thereby accounting for their existence. A satisfying feature of these results is the fact that the observed variation of the anomalous scattering with angle and with voltage permits of a simple and direct interpretation on the basis of the "wave-mechanics" which has so successfully met all previous requirements as a description of atomic phenomena. In terms of this theory the observed proton-scattering is accounted for as a simple scattering (phase-shift) of the spherically symmetrical wave-component by a "potential-well" (superposed on the Coulombian potential) which has almost exactly the depth and width previously assumed for the proton-neutron interaction. Furthermore, no appreciable effect on the higher wave-components appears to be required.

Certain aspects of these proton-scattering measurements are not entirely satisfactory, as may be expected of any first series of measurements on any important subject. The exact values of the scattering at low angles ( $15^\circ$  and  $20^\circ$ ) are in some doubt. This is due to a possible error in the zero-position of the angular scale which, having been removed after completing the experi-



ments and because of small uncertainty in its position after replacement, prohibited checking these low angles to the desired accuracy without repeating the whole experiment. Difficulties in measuring the number of protons in the primary beam passing through the scattering volume gave rise to undesirable fluctuations among different observed values of the scattering at a given voltage and angle; these errors were minimized by averaging for each angle the results of numerous independent determinations made at different times. Scattering observations which incorporate a better method for determining the primary proton-current are desirable. Lacking facilities for higher voltages, it is also important to extend these measurements to voltages below 600 kilovolts, using Geiger counters for detecting the scattered particles. Modifications are being incorporated in a new proton-scattering apparatus under construction to effect such improvements in the measurements, which will be repeated and extended.

Immediately after our announcement that these proton-scattering results led to a proton-proton interaction very similar to that hitherto assumed by theoretical physicists for the proton-neutron interaction, serious doubts were cast on the latter interaction by Goldhaber of the Cavendish Laboratory, who announced measurements on the scattering of neutrons by protons widely different from the expected values. We were just then undertaking similar measurements of nearly the same kind under well-defined conditions—possible through the use of artificial neutron-sources of high intensity. Because of the doubt arising from Goldhaber's measurements, however, a repetition of his neutron-scattering experiment was made, using the (carbon + deuteron)-neutrons instead of his photo-neutrons from deuterium. Our measurements agreed astonishingly well with the value predicted by theory. The observed cross-section for scattering was  $4.2 \times 10^{-24}$  cm<sup>2</sup>, whereas the values predicted by Wigner's theory of the deuteron lie between  $5.4$  and  $3.2 \times 10^{-24}$  cm<sup>2</sup> depending on the values taken for the excited level of the deuteron and for the exact energy of the carbon neutrons used (600 to 1200 kilovolts, probably about 900). These measurements are being refined and extended as the report-year ends.

It thus appears that the earlier conclusion by Breit on the basis of our proton-scattering results that the proton-neutron, proton-proton, and neutron-neutron interactions are identical is probably valid, and a real step has been made toward the final understanding of the forces underlying the structure and behavior of all matter.

#### NUCLEAR RESONANCE-TRANSMUTATIONS

Observations of the sharp resonance-transmutations produced by proton-bombardment of light elements as reported last year were greatly improved by the use of a direct-reading high-resistance voltmeter, as described below. Using this voltmeter, the potentials across the accelerating tube could be observed continuously and specified with an error not exceeding 2 per cent (relative voltages to 1 per cent). With this advance in technique, the positions of the resonances could be much more accurately located than was possible last year, giving a set of resonance-voltages which are already being used in other laboratories for the calibration of ion-beams of unknown

energy or distribution. Values available which have been determined to date are as follows:

Voltage	Element	Width	Voltage	Element	Width
328 kv	F	< 4 kv	892 kv	F	< 12 kv
440 kv	Li	11	942 kv	F	< 15

Besides serving as calibration-points for an absolute-voltage scale, however, these resonances have an important theoretical significance of their own. Just as in the case of atomic radiation, the width of a spectral line is determined by the probability of radiation. In the nuclear case the widths of gamma-ray lines such as the resonance-lines above are determined by the probability of transition to other states. It has long been possible to estimate the widths of such gamma-ray lines from nuclear theory. The above measurements, however, give, for the first time, experimental data sufficiently accurate to check on current theory. The experimental data are as yet too meager for any important conclusions to be drawn, but demonstrate that a sufficiently analytical technique to attack this problem has been achieved. The extension of the observations to other elements and to all energy-levels within our voltage-range thus becomes a matter of careful and extended measurements.

These resonance-transmutations promise to be of importance in still another manner. As mentioned by Breit below, information as to the range (distance of action) of the force involved, as well as to the type or mode of interaction, can be deduced for the neutron-proton interaction from experiments in which high-energy gamma rays are used to bombard deuterons. The hardest available gamma ray from radioactive sources is one of 2.6 million volts from mesothorium, whereas much higher energies are required for the experiments proposed above. Fortunately the gamma rays from lithium emitted in the 440-kilovolt resonance-process appear to be of about 17 million electron-volts (MEV), while those from the fluorine resonances are of about 5.5 MEV, thus promising to make available gamma rays of the required different high energies. The interaction of matter and radiation in a hitherto inaccessible region of energies is thus opened to investigation.

#### HIGH-VOLTAGE TECHNIQUE

The efforts of the group in the laboratory were largely concentrated during recent years on the development of a high-voltage technique for nuclear physics adequate to meet the rigorous analytical and quantitative requirements necessary for measurements on proton-proton scattering and other critically important problems. As above indicated, the discovery and study last year of sharp nuclear resonances provided the best possible kind of a test for the adequacy of this technique. Besides the obvious necessity for replacing the original roughly constructed high-voltage tube, which did not have accurately aligned electrodes, the major requirement of an accurate and reliable means for measuring the high voltage itself was demonstrated by these tests. After tests of other devices a design for a 10,000-megohm corona-free voltmeter-resistor was developed and the construction of such a unit was undertaken near the end of the last report-year. With the help of Dr. R. G. Herb of the University of Wisconsin, temporarily a member of our

staff, this device was constructed and calibrated. Its excellent performance has resolved the last objection to the technique as a whole.

The instrument comprises one thousand 10-megohm 1-watt metallized resistors, connected in groups of 20 between 12-inch metal shielding-discs two inches apart, to prevent corona along the unit, each disc also having a ring of  $\frac{3}{4}$ -inch tubing at its circumference, to prevent corona out into space. By spark-over between these rings the resistors are protected against impulsive transients. The whole unit is kept dust-free, to prevent corona, by being enclosed in a Textolite cylinder. This voltmeter is accurate to 2 per cent in absolute value, and voltage-differences are correctly measured within one per cent. One of its first applications was an exhaustive study of the voltage-fluctuations of the high-voltage equipment when in use. These fluctuations were found to be less than one per cent. A permanent high-voltage tube, with provision for accurate alignment of the successive electrodes, was also installed. This tube eliminates all motions of the focal spot—hitherto very disturbing and preventing really accurate observations. The installation, at the end of the report-year, of a new high-speed pump-unit and double-deflection head at the bottom of the tube, permits observations at either of two target-positions, thus greatly expediting the program of measurements.

Subsidiary investigations were made during the year to supply details of design for the pressure-sphere generator described in last year's report, which it is hoped may ultimately be installed here. These tests dealt with the dimensions and design of the disc-generator and with the precautions required in constructing a vacuum-tube to be operated in compressed air and to withstand a relatively high voltage for the tube-length available in such a construction. Both investigations showed the practicability of the proposed pressure-sphere design.

The tests on the "wave-front method" of Beams and Snoddy, mentioned in last year's report, led to a rather indefinite result. It appears that this method requires further development before it can be used as a practical source of high-energy particles. However, the limitations of the ordinary transmission-line type of accelerator were determined (an impractical length of vacuum-tube is required) and this led to the investigation of a new type of delay-unit (the delay of spark-gap breakdown itself) which may serve instead of the transmission-line. Further studies of the method are being made by Professors Beams and Snoddy at the University of Virginia. The method will certainly not displace the pressure-sphere in the voltage-region where the latter may be used, but very possibly will attain satisfactory development for use as an auxiliary equipment reaching into the still higher regions of energy above 20 MV.

#### MISCELLANEOUS

In cooperation with Dr. L. H. Rumbaugh of the Bartol Foundation, who supplied the pure isotope samples, studies were made of the transmutations produced when the separate isotopes of lithium are bombarded by protons and by deuterons. It was perhaps surprising to find that even these "classical examples" of artificial transmutation were not known with entire correctness. An excitation-level in  $\text{Li}^7$  about 350 kilovolts above the ground-

level was discovered, which is of considerable importance and interest in connection with theoretical calculations on this nuclear configuration. The apparent emission of neutrons from  $\text{Li}^6$  under deuteron-bombardment was also found. The latter must be confirmed by careful check-observations on other elements; these observations are still in progress.

It has not yet been found possible to make field-tests of the new method to study the high atmosphere using a modulated searchlight-beam, mentioned in last year's report. Progress has been effected, however, in its ultimate application through discussions and conferences with Professor Chapman and Dr. Bartels and with Vice-President P. R. Bassett of the Sperry Gyroscope Company.

An investigation of the spectrum of the gamma rays emitted as a result of the 440-kilovolt proton-resonance of  $\text{Li}^7$  was begun but was interrupted to give precedence to the proton-scattering observations. Observing the Compton recoil-electrons emitted from a thin-glass plate in the center of a cloud-chamber traversed by a magnetic field, indications were obtained that gamma rays of about eight MV may be emitted in addition to the 17-MV gamma rays which have been identified at Pasadena by measurements on electron-pairs.

After nine fruitful years of valuable service in our nuclear-physics program, Odd Dahl resigned in February 1936 to return to Norway where, as a member of the Michelsen Institute at Bergen, he will take part in similar lines of investigation. The personnel engaged in the work above reported included Tuve, Hafstad, Dahl (to February 18, 1936), Heydenburg (from September 16, 1935), Meyer (from March 16, 1936), Brown (to September 24, 1935), and Schmidt (from November 11, 1935), in addition to the temporary assistance of Herb (July 1 to September 15, 1935).

#### THEORETICAL-PHYSICS CONFERENCE

A second "Washington conference on theoretical physics" was held April 27 to 29, 1936, again under the joint auspices of the George Washington University and the Carnegie Institution of Washington acting through this Department. The subject was "Molecular physics." Some 50 investigators were present, representing 27 different institutions. Six sessions, devoted to the following topics, were held: (a) Strength of chemical bond; (b) velocity of chemical reaction; (c) Van der Waals' forces; (d) magnetism and molecular structure; (e) vibrations of polyatomic molecules; (f) isotopes in physical chemistry. As for the first Conference, the aim of the discussions was to clarify the present status of a few important theoretical difficulties and problems concerned in these topics in order that investigators actually attacking them might indicate to each other and examine together directions of possible progress.

It became clear that fields of such possibilities so thoroughly investigated in detail as those of these conferences require rigorous limitation to a few specific topics. It seems that the need for limiting the number of invited conferees is generally recognized. Both the first and second of these informal conferences, with the sole purpose of discussing limited specific topics, have proved their real and immediate value in furthering research and in giving

proper understanding of the results and significance of current experimental and theoretical investigations.

#### PUBLICATIONS

In addition to the publications noted in the "List of Publications" given elsewhere in this Year Book, three manuscripts were completed as follows: "Constant-potential technique for quantitative nuclear-physics studies" by Tuve, Hafstad, and Dahl, to appear in *Die Naturwissenschaften*; "Excitation-curves for fluorine and lithium" by Hafstad, Heydenburg, and Tuve, to appear in *Physical Review*; "The scattering of protons by protons" by Tuve, Heydenburg, and Hafstad, to appear in *Physical Review*.

Formal talks were presented as follows: Washington Meeting of the American Physical Society, April 30, 1936, by Tuve, Heydenburg, and Hafstad on "The scattering of protons by protons"; by Hafstad, Heydenburg, and Tuve on "Widths of nuclear resonance-levels and the calibration of ion-beam energies"; and by Tuve, Hafstad, and Dahl on "Constant-potential technique and equipment for very high voltages"; Gibson Island Conference of Johns Hopkins University, June 24, 1936, by Tuve on "The scattering of protons and neutrons." Hafstad spoke by invitation at the Physics Colloquium, Johns Hopkins University, December 19, 1935, on "Current problems in nuclear physics," and before the Physics Colloquium of the University of North Carolina, February 14, 1936, on "Resonance transmutations and scattering experiments using protons."

#### COOPERATION IN NUCLEAR PHYSICS AT UNIVERSITY OF WISCONSIN AND AT INSTITUTE FOR ADVANCED STUDY AT PRINCETON UNIVERSITY

Professor G. Breit of the University of Wisconsin continued as research associate and consultant in the nuclear-physics program. The following paragraphs summarize briefly the theoretical and experimental work done by him and his associates at the University of Wisconsin and while in residence during the past academic year at the Institute for Advanced Study with E. U. Condon and R. D. Present at Princeton.

*Coulomb wave-functions*—In making calculations in nuclear physics it is often necessary to know the wave-functions of particles moving in a Coulombian field. Some of the more useful functions were computed and their properties were investigated. The results were published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity* jointly with F. L. Yost and John A. Wheeler, and in the *Physical Review*. This work was a continuation of that done last year.

*Theory of disintegration of lithium under proton-bombardment*—The calculations of Ostrofsky, Breit, and Johnson were extended by Ostrofsky, Bleick, and Breit to take into account the variability of potential with velocity due to the exchange-character of nuclear forces. These calculations were published in the *Physical Review*. A very good agreement between the mass-defect of  $\text{Be}^8$  and the shape of the excitation-curve was found, interpreting the disintegration as being due to head-on impacts of protons and no such agreement was found using collisions of angular momentum  $\hbar$ . Later work (by Breit) showed, however, that the agreement for head-on

collisions is fortuitous and that an effective enlargement of the nuclear radius due to perturbations improves the agreement for  $L = \hbar$ .

*Theory of capture and scattering of slow neutrons*—Slow neutrons are known experimentally to be captured selectively and good neutron absorbers are known to be often poor scatterers. Previous theories were able to account for large absorption, but they were not able to account for the selectivity and the absence of strong scattering. These theories were insufficiently general inasmuch as they treated the nucleus as a center of attraction for the incident neutron rather than a collection of particles. Taking into account the "many-body" nature of the nucleus the present theory gives a proper account of the experimental facts. This work was done jointly with E. Wigner.

*Interpretation of experiments on proton-proton scattering* made by Tuve, Heydenburg, and Hafstad—According to calculation these experiments show that:

(a) There is a relatively large attractive field of force between two protons. The interaction potential is found to be equivalent to 11 MV in a distance of  $2.8 \times 10^{-12}$  cm.

(b) This interaction-potential is in agreement with that found from nuclear mass-defect calculations. This agreement is strong evidence for the essential correctness of present theories for light nuclei. Previously to the performance of the experiment there were as many adjustable constants in the theory as there were experimentally known numbers to fit. In the light of this result one may consider it as highly probable that the specific nuclear forces between protons are equal to those between neutrons.

(c) The interaction-energy between protons is found to be practically the same as that between protons and neutrons as derived from the scattering and absorption of slow neutrons in hydrogen. It may now be, therefore, regarded as probable that the specific nuclear forces between all nuclear particles (that is, forces between protons, forces between neutrons, and forces between protons and neutrons) are the same.

The photoelectric effect of the deuteron was investigated theoretically in collaboration with E. U. Condon. It was found that by experiments with hard gamma rays it should be possible to derive information about the range of force as well as the type of interaction (ordinary or Majorana) acting between proton and neutron.

## FIELD-WORK AND REDUCTION

### LAND MAGNETIC SURVEY

The major objective of the Section of Land Magnetic Survey during recent years has been the observation, collection, compilation, and discussion of data relative to the magnetic field of the whole Earth. Since only limited funds could be apportioned for the survey this year, many field-parties could not be supported; therefore, only a modest amount of field-work was done by the Department. The personnel of the Section during the year included Green as Chief of Section, with the help in the office of Duvall for full time and of Wallis, Forbush, and Johnson for part time. Those engaged in

field-work part of the time during the year were Parkinson of the regular staff, and Mansfield, Brown, and Kwei of the temporary staff. Some service was given to the Section's activities in the office by Kwei and Slaucitajs, guest physicists.

Cooperation with the Aerial, Geological, and Geophysical Survey of Northern Australia was put into effect through the loan of magnetometer-inductor 18 which was delivered to the Survey in March 1936 after comparisons at Cheltenham and at Watheroo. L. A. Richardson of the Survey spent a week during March 9 to 16 at the Watheroo Observatory for instruction and training in the technique of magnetic observations and computations.

Least-square adjustment of the observations of magnetic declination in the Pacific by the *Galilee* and *Carnegie* to determine secular variation in that element was continued by Duvall throughout the year.

#### FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Brief accounts of field-operations referred to above are given in more detail in the following paragraphs.

*Africa*—As was the case during the past year, cooperative work with the University of Cape Town was continued by the loan of magnetometer-inductor 17 which is used for absolute control at the Cape Town Observatory.

*Asia*—Cooperative work in China under the direction of F. C. Brown, formerly observer of the Department and now connected with the American Church Mission at Hankow, assisted by Dr. C. T. Kwei of the Central China College at Wuchang, was continued. Periodic observations were made by Brown and Kwei at the Wuchang station September 1935 to July 1936. During October 1935 Brown obtained comparisons between his CIW magnetometer-inductor and the standards of the Zôsé Observatory. During July and August Kwei made a trip in south China where he occupied the following stations: Hengchow, Shingchow, Canton, Wuchow, Nanning, and Kweilin. Brown will leave China in July 1936 for a trip to the United States and will bring with him to Washington CIW magnetometer-inductor 13, which has been in use in China for a number of years, for determination of corrections on standards and for thorough overhaul before resumption of field-work in China on his return late in 1936.

*Australasia*—After transferring charge of the Watheroo Magnetic Observatory to Green at the end of January 1936, Parkinson took up an extensive program of field-work in Australasia and the Pacific Islands which will extend over several years. It is intended that, in addition to observations on the continent of Australia and the Island of Tasmania, this field-trip will include reoccupations in New Caledonia, Loyalty Islands, New Hebrides, Solomon Islands, New Guinea, Lord Howe and Norfolk islands, Cook Islands, and Society Islands. During a short field-trip to the southwest of Western Australia in February, Bunbury was reoccupied and a new station was established at Albany. Early in March, Parkinson again left the Observatory en route for Sydney, traveling overland by utility truck. During the journey the following eight stations were occupied: Merredin, Coolgardie, Balladonia, and Eucla, in Western Australia; Ceduna, Port Augusta, and Adelaide (where intercomparisons were obtained with the magnetic instruments of the Adelaide Observatory), in South Australia; and Portland, in Victoria. After representing the Department and the Institution at the Fifth

Conference of Physicists and Astronomers at Sydney during the latter part of May, Parkinson proceeded with field-work in Queensland and New South Wales. By the end of June 1936 he had occupied: Red Hill, Woolgoolga, Moree, and Werris Creek, in New South Wales; Brisbane, Toowoomba, Roma, Tambo, Long Reach, Clermont, Rockhampton, and Maryborough, in Queensland.

The usual control-observations for magnetograph base-lines were maintained at the Watheroo Magnetic Observatory.

*Europe*—Upon the completion of his work in Africa at the end of June 1935, Mansfield proceeded to Europe, where he obtained intercomparisons of his magnetometer-inductor 18 with the standards of the Niemegk (Germany) and Abinger (England) observatories.

*North America*—There has been rather extensive comparison work during the year in connection with the transfer of the International Magnetic Standards of the Department, as heretofore maintained at its Standardizing Magnetic Observatory at Washington, to the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey (see section on observatory-work). Observations were made at Cheltenham to determine corrections on standards for magnetometer-inductor 18 upon its return from the long trip in Africa and Europe and after its overhaul before being sent to Australia. Additional observations at Cheltenham were obtained in the comparisons there of magnetometer-inductor 28 and CIW sine-galvanometer 1, and comparisons between Schulze CIW earth-inductor 3 and the Observatory earth-inductor 26. Comparisons were also obtained between quartz horizontal-intensity magnetometer 2 (QHM 2) of the la Cour design with CIW sine-galvanometer 1 in February 1936. This first test of a QHM is in connection with Dr. la Cour's tests to determine upon the feasibility of obtaining calibrations of horizontal-intensity standards by maintaining a mailing circuit between observatories of instruments of the QHM-type.

*South America*—Secular-variation data were obtained through the control-observations made at the Huancayo Magnetic Observatory.

Results of observations for the three elements obtained by officers of the United States Hydrographic Office in Columbia at Puerto Colombia and at Cartagena during December 1935 were received.

### OBSERVATORY-WORK

In the Section of Observatory-Work Johnston was assisted by Ledig, Forbush, and Miss Balsam, and had part-time assistance from McNish, Ennis, and Hendrix. The members of the staff engaged at the observatories are mentioned in the respective reports.

### OPERATIONS AT OBSERVATORIES

The operations during the report-year at the observatories of the Department and at observatories with which the Department cooperated are summarized below.

*Watheroo Magnetic Observatory, Western Australia*—The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ} 19' 1''$  south and longitude  $115^{\circ} 52' 6''$  east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was operated continuously throughout the year with no actual loss of trace though a somewhat broken record was obtained during March on account of readjustments on the horizontal-



intensity ( $H$ ) variometer. The axis of the magnet-system of this instrument was found to be  $6^{\circ}5'$  out of the magnetic prime-vertical. After readjustment it was necessary to place a control-magnet on this variometer in order to secure a workable scale-value.

The vertical-intensity scale-value observations were made daily throughout the year by the electrical method while the magnetic method was used for the monthly determination of horizontal-intensity scale-value. The monthly mean scale-values for the two components for the calendar year 1935 are shown in table 1.

TABLE 1—*Eschenhagen scale-values, Watheroo Magnetic Observatory, 1935*

Month	Scale-values in $\gamma/\text{mm}$		Month	Scale-values in $\gamma/\text{mm}$	
	Z (means daily values)	H (reduced to base-line)		Z (means daily values)	H (reduced to base-line)
January.....	4.62	2.65	July.....	4.04	2.66
February.....	4.70	2.66	August.....	4.04	2.66
March.....	4.71	2.66	September.....	4.08	2.67
April.....	4.70	2.66	October.....	4.01	2.68
May.....	4.55	2.68	November.....	3.93	2.70
June.....	4.48	2.67	December.....	4.15	2.68

The la Cour rapid-running magnetograph was in continuous operation with the exception of short periods when the driving mechanism failed or when adjustments were necessary. Scale-value determinations by the electrical methods were made monthly as usual and in the case of the  $H$ -instrument are very consistent. The values for the vertical-intensity ( $Z$ ) variometer were also quite consistent for the first half of the year but showed a distinct upward tendency during the last half of the year. The values for both variometers, as derived from the monthly determinations, are given in table 2.

TABLE 2—*Scale-value determinations by electrical method, la Cour rapid-running magnetograph, Watheroo Magnetic Observatory, 1935*

Month	Scale-values in $\gamma/\text{mm}$		Month	Scale-values in $\gamma/\text{mm}$	
	H	Z		H	Z
January.....	4.70	2.39	August.....	4.56	2.58
February.....	4.73	2.47	September.....	4.56	2.78
March.....	4.67	2.50	.....	.....	3.09
April.....	4.66	2.53	October.....	4.66	3.13
May.....	4.62	2.46	November.....	4.52	3.32
June.....	4.58	.....	December.....	4.60	3.41
July.....	4.64	2.67			

The Mitchell vertical-intensity inductometer was in operation throughout the year. The times of sudden commencements of magnetic disturbances as recorded by this device were forwarded to the Office from time to time as

they occurred, the traces were appropriately marked and stamped and forwarded with other records obtained at the observatory.

The preliminary mean values of the magnetic elements for all days of the year 1935, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive are: Declination,  $-3^{\circ} 42'5''$ ; horizontal intensity, 0.24672 CGS unit; vertical intensity,  $-0.51379$  CGS unit; and inclination,  $-64^{\circ} 21'0''$ . The preliminary values for the annual changes in the magnetic elements during 1934.5 to 1935.5 are: Declination,  $+5'3''$ ; horizontal intensity,  $+3$  gammas; vertical intensity,  $-39$  gammas; and inclination,  $-0'9''$ .

A series of intercomparisons by simultaneous observations was made between the standard instruments of the observatory—CIW magnetometer 7 and earth inductor 2—and CIW magnetometer and inductor 18, the latter instrument having been compared at Cheltenham with the Department's sine-galvanometer during October 1935. Intercomparisons were also made between CIW magnetometer-inductor 28 and standards of the observatory through values scaled from the magnetograms.

Continuous records of earth-potentials, for derivation of diurnal variations in earth-currents, were made throughout the year over the system of electrodes as described in previous reports. A few scattered days were lost but the total amount of record lost was negligible.

Air-potentials were recorded continuously with the standard potential-gradient apparatus as in former years and the usual monthly "reduction-factor" determinations were made, the results being given in table 3.

TABLE 3—Factor to reduce recorded volts to the potential at a point one meter above ground over a plane surface, Watheroo Magnetic Observatory, 1935

Month	Reduction-factor	Month	Reduction-factor
January.....	1.11	July.....	1.10
February.....	1.09	August.....	1.15
March.....	1.11	September.....	1.13
April.....	1.09	October.....	1.09
May.....	1.11	November.....	1.08
June.....	1.13	December.....	1.09
Mean for year 1935..... 1.10			

Table 4 gives the annual mean values of this "reduction-factor" for the past seven years.

TABLE 4—Annual mean values of reduction-factor, Watheroo Magnetic Observatory, 1929–1935

Year	Factor	Year	Factor
1929.....	1.12	1933.....	1.11
1930.....	1.11	1934.....	1.10
1931.....	1.12	1935.....	1.10
1932.....	1.11		

The preliminary mean value of the potential gradient derived from 196 complete days of the year 1935 is 75.5 volts per meter.

The number of days during each month when normal records were obtained, the mean value of the gradient, and the seasonal variation are shown in table 5.

TABLE 5—*Preliminary mean monthly values of potential gradient at Watheroo Magnetic Observatory, 1935*

Month	No. days	Potential gradient in v/m	Month	No. days	Potential gradient in v/m
January.....	10	82.1	July.....	12	63.8
February.....	9	89.7	August.....	13	81.4
March.....	11	70.3	September.....	22	77.0
April.....	16	65.6	October.....	24	79.2
May.....	17	57.6	November.....	22	83.6
June.....	20	64.4	December.....	20	91.3

Positive ( $\lambda_+$ ) and negative ( $\lambda_-$ ) air-conductivities were recorded throughout the year and the usual control-observations were made regularly. Table 6 gives preliminary values of the conductivities in electrostatic units as recorded during 214 complete days of 1935.

TABLE 6—*Preliminary monthly mean values of air-conductivity, Watheroo Magnetic Observatory, 1935*

Month	Number complete days	Air-conductivity, units $10^{-4}$ esu			Ratio $\lambda_+/\lambda_-$
		$\lambda_+$	$\lambda_-$	$\lambda_+ + \lambda_-$	
January.....	12	1.61	1.49	3.10	1.08
February.....	10	1.53	1.25	2.78	1.22
March.....	9	1.92	1.80	3.72	1.07
April.....	15	2.26	2.01	4.27	1.12
May.....	18	2.46	2.23	4.69	1.10
June.....	19	2.58	2.35	4.93	1.10
July.....	22	2.28	1.95	4.23	1.17
August.....	21	2.09	1.83	3.92	1.14
September.....	18	1.84	1.59	3.43	1.16
October.....	28	1.73	1.59	3.32	1.09
November.....	15	1.63	1.42	3.05	1.15
December.....	27	1.53	1.42	2.95	1.08
Total or means.....	214	1.96	1.74	3.70	1.12

The narrow sector directional atmospheric recorder, on loan from the Australian Radio Research Board of the Council for Scientific and Industrial Research, was kept in continuous operation throughout most of the first half of the report-year, but was out of commission from the latter part of December 1935 until the latter part of March 1936, while attempts were being made to adjust the "sense-device." With this device working at efficiency about 50 per cent, continuous recording was resumed March 26, 1936, and daily reports, except Sunday, have been made to the Radio Research Aerodrome at Laverton, Victoria, by means of coded telegrams, these reports being the results of preliminary analyses. During the last three months of the report-year the traces were forwarded to the Melbourne Office of the Research

Board weekly, together with a copy of the preliminary analysis. A considerable amount of time has been spent on this apparatus and it still does not function properly. It is hoped that the Research Board will see fit to rebuild the apparatus using new and improved units, when the present program shall have been completed.

The ionospheric equipment was in continuous operation during the report-year with the exception of short intervals when our S. L. Seaton, who is in charge of its operation, was on leave and in attendance at the Fifth Conference of Physicists and Astronomers in Sydney, May 25 to 28, 1936. Determinations of layer-heights and critical frequencies were made in accordance with a regular schedule. Preliminary reduction of the observational data was done and the compilations were forwarded to Washington at regular intervals. Brief reports of layer-heights and critical-frequencies obtained from regular ionosphere-runs were forwarded directly to Washington by radio, usually through station W3AMS at Washington Grove, Maryland, and usually on the day the run was made. Schedules of communication were maintained between the Observatory and Washington, for the most part with station W3AMS mentioned above, with but infrequent interruptions, throughout the year. From July 1, 1935, to June 30, 1936, a total of 262 messages had been sent from the Observatory and 52 had been received from Washington. Magnetic character of days was reported to Washington weekly by this means.

The Hale spectrohelioscope was used for observations of solar eruptions during the early part of the year.

The usual meteorological observations, including sunshine-record, nuclei-count, etc., were obtained daily and all the self-recording meteorological instruments were kept in continuous operation. Data were supplied monthly to the Commonwealth Weather Bureau in Melbourne as in former years.

On account of the change in the Observer-in-Charge February 1, 1936, and the extra time necessary for the new Observer-in-Charge to become familiar with the administrative duties, the reductions and tabulations of magnetic and atmospheric-electric data have fallen somewhat in arrears but it is expected that this condition will not last long.

The Delco and 110-volt power-plants and the auxiliary electrical equipment were maintained in running order. In December two 110-volt, 2-kw direct-current Kohler generators were received and installed in the powerhouse to eventually replace the 32-volt Delco generators and to supply the extra power necessary for the additional ionospheric equipment soon to be delivered.

Necessary attention was given to maintenance of site, buildings, and general equipment, all of which are in excellent condition. The water-supply problem became somewhat serious during the year as the long-continued drought has depleted almost entirely the wells, and the rainfall, much below normal, was insufficient to provide the usual supply from catchment-basins. Arrangements are being made to drive an artesian well in the hope of securing a good flow within 200 or 300 feet. The acute water-shortage prevailed from January 1936.

Parkinson continued as Observer-in-Charge until February 1 when he was succeeded by Green. The two junior observers, Culmsee and Hogan, continued their excellent service. Seaton, in charge of the ionospheric program and of radio communication, can not be commended too highly for his large share in the success of the work. Oldham served as mechanic and electrician throughout most of the year.

The support and cooperation of various departments of the State and Commonwealth, so generously given as in the past are gratefully acknowledged. Particular mention should be made of the Department of Trade and Customs of the Commonwealth of Australia for assistance in the importation of equipment and of the Wireless Branch of the Postmaster General's Department whose officials have done much to forward the ionospheric research. Professor A. D. Ross of the University of Western Australia continued as the patron-saint of the Observatory and his continued interest and assistance in the activities of the Observatory are of great value.

*Huancayo Magnetic Observatory, Peru*—The Huancayo Magnetic Observatory is situated in latitude  $12^{\circ} 02' 7''$  south and longitude  $75^{\circ} 20' 4''$  west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 meters (11,000 feet) above sea-level.

Eight major pieces of apparatus were in continuous use throughout the report-year, together with several lesser instruments used in obtaining meteorological data. Of the eight major items of equipment, seven are of the photographically recording type.

Two magnetographs—the rapid-running la Cour and the Eschenhagen—were operated. Weekly absolute observations for the control of base-line were made regularly. Electrical scale-value determinations for the horizontal- and vertical-intensity variometers of the la Cour magnetograph were made about the fifteenth of each month. Scale-values for all three variometers of the Eschenhagen magnetograph were also obtained electrically by Helmholtz coil—for the declination and horizontal-intensity variometers once each week and for the vertical-intensity variometer three times each week. Since, with the Helmholtz-coil method of obtaining scale-values, the variometers are not touched or handled, very satisfactory scale-values and very good records with the vertical-intensity variometer, which is of the knife-edge type, were obtained. For the eight months, November 1935, through June 1936, the scale-value has varied only between 3.69 and 3.71  $\gamma$  per mm. There continues to be gradual shifting of the magnet of the vertical-intensity variometer; this is, however, so regular and of such small magnitude that it is easily allowed for in the reduction of the records.

The preliminary mean values of the magnetic elements for all days of 1935 as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive are: Declination,  $+7^{\circ} 15' 2''$ ; horizontal intensity, 0.29612 CGS unit; vertical intensity,  $+0.01130$  CGS unit; and inclination,  $+2^{\circ} 11' 2''$ . The preliminary values for the annual changes in the magnetic elements, based on these values and on the *final* values for 1934 are: Declination,  $-2' 9''$ ; horizontal intensity,  $-10 \gamma$ ; vertical intensity,  $+23 \gamma$ ; and inclination,  $+2' 7''$ .

Air-potentials were recorded continuously with a standard potential-gradient apparatus, and scale-values were determined weekly. Nine determinations during 1935 of the factor to reduce recorded volts to volts at a point one meter above an open level plain, gave an average value of 1.18, which is in good agreement with the value for the years 1933 and 1934, namely, 1.16. The preliminary mean-value of the atmospheric potential-gradient derived from 157 selected days in 1935 was 51 volts per meter; the groups of 117 days in the dry season from April to September and of 40 days in the wet season gave like values of 51 volts per meter. In 1934 the mean was also 51 volts per meter.

The apparatus to record positive and negative conductivity of the atmos-

phere functioned well and scale-value determinations were made weekly, giving satisfactory control throughout the year. The preliminary mean-value for 157 selected days in 1935 was  $3.28 \times 10^{-4}$  electrostatic unit for the positive conductivity and  $4.03 \times 10^{-4}$  electrostatic unit for the negative conductivity. The twelve monthly values of total conductivity for 1935 in terms of  $10^{-4}$  electrostatic unit were 6.53, 5.87, 5.48, 6.99, 7.03, 7.35, 8.45, 6.52, 8.10, 7.66, 8.42, and 9.26.

Earth-current potentials were measured with two sets of electrodes known as Systems I and III. The electrode-systems were maintained in good operating condition and practically no loss of record was experienced. The recorder, however, was shut down during nearby thunder-storms, thus preventing damage to the apparatus which might have caused serious interruption in recording.

Daily observations, if clouds permitted, were made with the Hale spectrohelioscope, of solar prominences and spots, during the two half-hour periods beginning at 15<sup>h</sup>30<sup>m</sup> and 16<sup>h</sup>30<sup>m</sup> Greenwich mean time. Considerable difficulty was experienced in 1934 and 1935 in getting the spectrohelioscope to function, and in 1935 and 1936 in developing a satisfactory procedure of observing and recording. However, in the later months of the report-year the program had been arranged on a fairly satisfactory basis. A noteworthy solar eruption on April 8, 1936, with coincident disturbances in magnetism and other geophysical elements was made the subject of communications to the *Journal of Terrestrial Magnetism and Electricity* and to *Science*. Monthly reports of solar disturbances were forwarded to Washington for the preparation of quarterly reports to the Commission No. 11 of the International Astronomical Union.

Seismograms were obtained throughout the year with two Wenner horizontal-component seismometers and a Benioff vertical-component seismometer. Interpretations of important disturbances were promptly prepared and forwarded to Washington by radio, when radio conditions were satisfactory. Considerable interruption to radio schedules was, however, experienced through the year. Copies of the reports were also sent by air-mail weekly, together with other reports and correspondence.

Besides monthly reports on solar and seismic disturbances, monthly reports were also forwarded to Washington on magnetic disturbances.

The automatic ionospheric recording-equipment, which was installed in April and May 1935, was in continuous operation through the year, except for periods during which special polarization-tests were made in July, August, September and October 1935. Earliest recording on a fixed frequency was done at 4400 and 4600 kc but, following the tests in October 1935, fixed-frequency recording was resumed at 4800 kc and has since been maintained at that frequency. The fixed frequency throughout was done with an antenna placed in the northwest-southeast direction, the wire being 48 meters long and the height above the ground averaging 12 meters. The fixed-frequency recording was regularly interrupted in accordance with a cooperative schedule providing for multifrequency runs on certain days and at specified times. On Monday and Wednesday of each week, multifrequency runs of eight to ten hours duration were made with frequency-range—made every minute by manual adjustment—extending from 2500 kc to 9500 kc in steps of 100 or 200 kc., in each hour. Additional multifrequency runs, of one-hour duration, were made during the latter part of the report-year and on several other occasions through each week. The multifrequency runs were analyzed promptly and the data forwarded to Washington twice each month. Fre-

quent reports of conditions of operation and discussions of the data obtained were submitted.

The 110-volt, direct-current, power-system—placed in service when recording was begun with the automatic ionospheric apparatus—was little by little put to service on other instrumental installations and on the residential load. By December 19, 1935, the change-over to the 110-volt power-system was completed and the old 32-volt system was abandoned. Power for the 110-volt system is derived chiefly from two 2-kw Kohler plants, operated alternately for 24 hours; these plants gave satisfactory service with about 90 per cent of rated output at the considerable elevation of this observatory.

In accordance with plans of the Carnegie Institution's Committee on Coordination of Cosmic-Ray Investigations, precise cosmic-ray meter C-2 was installed just before the end of the report-year. A specially insulated cosmic-ray laboratory was attached to the south side of a new anemograph building constructed during March to May 1936. With 36 inches of space between the outermost and innermost walls of the cosmic-ray laboratory—the outer 20 inches packed with straw, six inches of air-space, and the inner ten inches packed with straw—there is no temperature-variation within the laboratory in response to the diurnal variation of temperature outdoors. The meter, designed by A. H. Compton and R. D. Bennett, is described in *Review of Scientific Instruments* for December 1934. Meter C-2 was placed May 16, 1936, and its installation was completed June 10, 1936. Records have been obtained continuously since that date, a noteworthy feature of the recording being the number of "bursts" found daily.

Meteorological observations, including barometric pressure, maximum and minimum temperatures, relative humidity, rainfall, cloudiness, and wind-direction and velocity, were made daily at 8°, 75° west meridian time. At this same hour daily, measurements of the content of condensation-nuclei in the atmosphere were made. Continuous records were obtained with barograph, thermograph, hydrograph, anemograph, and sunshine-recording.

Computations and tabulations associated with the magnetic, atmospheric-electric, earth-current, ionospheric, and meteorological studies were kept strictly current, and the traces, tabulations, and records were forwarded to Washington monthly. Seismograms were forwarded to Washington twice each month and the control-records for the seismographs were forwarded at the end of each month. The records of the spectrohelioscope and notes were forwarded at the end of each month.

In cooperation with the Peruvian Government and its branches, various data were supplied. Tabulations were supplied each month to the Servicio Meteorológico Nacional of the daily meteorological observations and of the hourly values of barometric pressure, wind-direction, wind-velocity, and sunshine. Meteorological data are also supplied at frequent intervals to the Engineer of the City of Huancayo. In March and April 1936, a barograph was standardized for the Junin Station of the Comisión Agronómico.

O. W. Torreson continued as Observer-in-Charge throughout the report-year, with W. E. Scott as first assistant observer, and H. E. Stanton as observer responsible for the ionospheric investigations. Observer H. W. Wells and Mrs. Wells returned to Washington early in the report-year, leaving the Observatory August 16, 1935. T. Astete and A. Macha continued as temporary clerical assistants.

The Observatory, as in the past, enjoyed the helpful friendship of the local residents. The American Consulate gave valuable assistance to mem-

bers of the staff entering Peru and to the Observatory in various directions. The American Embassy extended valuable aid in arranging for free entry of materials and equipment for the Observatory, although for the last half of the report-year this privilege has been withdrawn by the Peruvian Government, a decree dated December 7, 1935, having been handed to the American Ambassador on December 24, 1935, to that effect. It is to be hoped that free-entry privileges will ultimately be restored.

#### COOPERATION WITH OTHER OBSERVATORIES

*Apia Observatory, Western Samoa*—The cooperative work of the Department in atmospheric electricity and terrestrial magnetism with the Apia Observatory (latitude  $13^{\circ} 48'$  south, longitude  $171^{\circ} 46'$  west), which began in 1921, was continued. Besides those fields, the Observatory does extensive work in seismology and meteorology.

As in former years, the magnetic instruments used were the Tesdorpf magnetometer and the Schulze earth-inductor, the former being employed for measurements of declination and horizontal intensity and the latter for measurements of the dip. In addition to these instruments, the Observatory has Eschenhagen variometers which give a continuous photographic record of the declination and the horizontal force and a Godhavn balance which gives continuous records of the vertical force.

CIW theodolite-magnetometer 9, which the Department loaned for temporary use at Apia, arrived in Samoa during July 1935. Intercomparison between this instrument and the Tesdorpf magnetometer belonging to the Observatory were commenced in September and completed in December, whereupon the Tesdorpf magnetometer was sent to Germany for overhaul. The results show that the Tesdorpf magnetometer required the following corrections to be applied to it to reduce its results to the International Magnetic standard: Declination,  $-2.5$ ; horizontal force,  $-0.00063H$ .

A discontinuity which arose in April 1935 in the base-line value of the variometer for declination has been traced to a defect in collimation in magnet 13.

Owing to the bad state of repair of the roof of the magnetograph-house, the *D*- and *H*-variometers were removed to the west room May 20, 1936.

A Benndorf electrometer continued to be used to record values of air potential-gradient at the "Land Station" in the grounds of the Observatory. An experiment to determine the factor for reducing observed values of potential to volts per meter, made September 13, 1935, gave a value of 1.13, which agrees with the value found in May 1935 but is higher than the value of 1.00 adopted in the preliminary reduction of the results for previous years. The monthly mean values of atmospheric potential-gradient during 1935 at Apia are as follows, expressed in volts per meter: January, 100; February, 94; March, 111; April, 100; May, 99; June, 115; July, 126; August, 140; September, 117; October, 107; November, 106; December, 116. Mean for the year is 111 volts per meter.

A certain amount of time was devoted to the Gerdien and Ebert apparatus—the property of the Observatory—for measuring the conductivity of the air and the number of ions. The results were disappointing, and it was decided that the instruments themselves are too old to give satisfactory service.

The work in meteorology at Apia during the year 1935-36 consisted of observations at the surface twice a day and some measurements of the upper winds from time to time using pilot-balloons. The times of the daily ob-



servations are 9<sup>h</sup> and 15<sup>h</sup> zonal time of 165° west meridian. The method used with pilot-balloons has been normally the method of the single theodolite. During the week March 16 to 21, 1936, ascents were made at 7<sup>h</sup> GMT in conjunction with the International Meteorological Organization. The balloons had to be observed on this occasion by means of small lanterns carried by them because the adopted time of observation was after nightfall in Samoa. The total number of pilot-balloon ascents during the year under review is 108.

The Observatory continued to receive reports of rainfall from about 20 local stations in the Samoan Islands and to issue these reports to the local newspaper for publication. In addition, the Observatory supplied this newspaper with predicted tide-tables and the phases and times of rise and set of the moon.

The Observatory also continued to prepare synoptic charts of the weather in the South Pacific, using the weather-reports received every day by the Radio Station. The area covered by these reports stretches from the region of the New Hebrides and Solomon Islands eastward to the Society Islands, the Marquesas and the Gambier Islands, and includes about 20 stations or more that send in regular reports. During the season of hurricanes the Observatory prepared a daily weather report for display at the Post Office and Customs Office and issued warnings of cyclones.

TABLE 7—*Meteorological summary, Apia Observatory, 1935*

Month	Pressure	Temp.	Rainfall	Rel. hum. (9 a. m.)	Sunshine	Wind- velocity
	<i>inches</i>	<i>°F</i>	<i>inches</i>	<i>per cent</i>	<i>hours</i>	<i>miles/hr.</i>
January.....	29.740	78.6	40.88	79	82.3	7.9
February.....	29.771	80.1	4.24	82	221.0	7.1
March.....	29.786	79.8	22.56	81	166.8	7.1
April.....	29.812	79.5	4.02	82	229.9	7.4
May.....	29.855	79.0	4.84	81	221.0	6.5
June.....	29.873	78.7	2.71	81	246.6	9.5
July.....	29.843	79.1	3.05	81	250.9	7.9
August.....	29.888	78.2	8.73	80	227.3	8.2
September.....	29.858	79.5	7.00	82	245.3	7.9
October.....	29.851	80.7	3.61	83	259.3	8.8
November.....	29.802	79.8	15.45	82	170.9	5.4
December.....	29.757	79.2	16.40	81	160.6	7.7
Mean or total..	29.820	79.4	133.49	81	2481.9	7.6

Wadsworth left Samoa on furlough July 30, 1935, and returned February 13, 1936, after having been delayed in New Zealand by illness. He was relieved during his absence by H. F. Baird who arrived in Samoa on July 24, 1935, and who left February 8, 1936. The present staff consists of J. Wadsworth (Director), W. R. Dyer, H. B. Sapsford, four clerks recruited locally, and a Chinese assistant.

*Tucson Observatory, United States*—Registration of air-potentials and of positive and negative air-conductivity, with control-observations and tests, were continued by Observer-in-Charge J. Wallace Joyce and assistants of the United States Coast and Geodetic Survey, cooperating with the Department. As in past years since initiation of the atmospheric-electric pro-

gram and for use in that program, we were supplied by the War Department with the complete meteorological data obtained at the Tucson Airport of the Meteorological Service of the United States Signal Corps. The registration of earth-currents, under a cooperative arrangement with the Mountain States Telephone and Telegraph Company, was also continued. The scalings of all records were made at the Observatory by Mrs. G. Dewey.

*Cheltenham Magnetic Observatory*—The installation of CIW sine-galvanometer 1 was completed at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey in May and June 1935 (see last year's report). After suitable comparisons in horizontal intensity between that instrument and the Observatory's standard Wild magnetometer 26, sine-galvanometer 1 replaced the latter as Observatory standard in August 1935. The standard CIW Schulze earth-inductor 48 of the Department was also transferred to the Observatory to control International Magnetic Standard in inclination there. Cooperation between the two organizations continued in instrumental developments, testing of instruments including operation of CIW permivar vertical-intensity induction-vario-meter, and general improvement of technique and accuracy. The precision cosmic-ray meter installed in January 1935 in cooperation with the Carnegie Institution of Washington operated throughout the report-year; general supervision of its operation and records was by Forbush with some assistance from Johnson, both of the Department.

*College, Alaska*—Active cooperation was maintained with the University of Alaska at College, Alaska, in the design and installation of ionospheric equipment for manual multifrequency measurements. Work has progressed so far that measurements will be begun in the near future. An auxiliary power-supply for use in summer, when the University plant is closed, was provided and installed during the summer. The work at College is in charge of Professor E. H. Bramhall of the Department of Physics who spent several months at the Department, before proceeding to Alaska, in the study of the technique and the interpretation of the measurements.

*Installation of precision cosmic-ray meters*—Of the seven precision cosmic-ray meters constructed by Professor A. H. Compton for the Institution's Committee on Coordination of Cosmic-Ray Investigations, three were installed. These were in operation at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey from January 1935 (see Year Book 34, p. 257), at the Christchurch (Amberley) Magnetic Observatory of the New Zealand Department of Scientific and Industrial Research from April 1936, and at the Huancayo Magnetic Observatory of the Department from June 1936. Well-insulated frame buildings to house the meters were constructed at each of these observatories and also in June 1936 on the grounds of the Observatorio Astronomico Nacional at Tacubaya, D. F., Mexico.

Based on the early experience with the meter at Cheltenham, a manual of instructions for the installation and operation of these meters was prepared by Fleming and Forbush and was published. Various difficulties encountered in the operation of the meter at Cheltenham were examined and corrected as far as possible. Most of these concerned possible inadequate insulation between the central electrode and the wall of the main chamber.

Preliminary analyses of the data obtained at Cheltenham were made in order to investigate the performance of the meter. Such analyses for the intervals April 20 to June 30, 1935, August 1 to September 26, 1935, and March 1 to May 19, 1936, yielded barometric coefficients which are

statistically in agreement and further indicated that the barometric coefficient does not change with time of day. The harmonic analyses so far made of the data, after applying the barometric coefficient, indicate the existence of a statistically *real* diurnal variation.

#### REDUCTION OF MAGNETIC DATA

*Magnetic data from Watheroo and Huancayo magnetic observatories*—The activities of the Section of Observatory-Work were practically confined to working intensively on the reductions of Watheroo and Huancayo magnetic data. Utilizing the improved methods which the Department has developed in the course of years, good progress was made. The necessary memoranda and directions for procedure at observatories were prepared as required.

As pointed out in last year's report (p. 260), an important procedure is to test alignment of axes of magnet-systems of the variometers. Tests of the orientations of the variometer-magnets at Watheroo were made during the year. The magnet of the Eschenhagen variometer recording declination was found to be adjusted correctly in the magnetic meridian, that of the vertical-intensity variometer was in the horizontal plane, but the tests showed that the horizontal-intensity variometer was  $6^{\circ}25'$  out of the magnetic prime-vertical. An examination of the data relating to the last-named variometer during 1919-35 indicated that until August 1921 the axis of the magnet-system was in the prime vertical within the tolerance which may be allowed. However, in August 1921 a readjustment of the magnet was made in which it was oriented approximately  $6^{\circ}$  from the magnetic prime-vertical. In view of the practical difficulties met in any attempt, involving both variations in declination and horizontal intensity, to correct tabulated hourly data for this deviation from the magnetic prime-vertical, the hourly values of horizontal intensity as already compiled will be published for the meridian in which they were recorded, suitable notations being added to tabulations. Since the computed values of diurnal variations, non-cyclic changes, and monthly averages are used in most theoretical investigations, it is proposed that these computed values be revised to correct for the contribution of variation of declination to the observed variations of horizontal intensity in an orientation other than the prime vertical. However, it must be stated that for any investigation previously undertaken, the spurious contribution would not have affected any theoretical conclusions; the revision is nevertheless necessary since more accurate tabulations may be necessary for future studies.

In the meantime the reductions for Watheroo Magnetic Observatory for 1934 have been concluded. The hourly values, diurnal variations in all elements, non-cyclic changes, monthly averages, and description of magnetic activity are completed. Preliminary reductions have been made for 1935, and preliminary values of the annual means of the elements at Watheroo, based on all days, are given in table 8.

Tests of the alignment of the axes of magnet-systems at the Huancayo Observatory showed them to be correctly oriented. All tabulations of hourly values in vertical intensity during 1926-1934, when the variometer's mag-

netic axis was 3°4 from horizontal, were revised. Diurnal variations in declination, inclination, and the three intensity-components during 1922-34 were computed. The hourly means of declination, horizontal intensity, and vertical intensity were computed for 1935. The final values of the elements during 1926-34 and the preliminary values for 1935 are summarized in table 8. It is to be noted that these values supersede the provisional one published in previous annual reports. The records furnished by the rapid-run la Cour magnetograph were utilized to supply values for times during 1934 and 1935 when there were, for one reason or another, defective records by the Eschenhagen magnetograph.

TABLE 8—Annual values of the magnetic elements at the Watheroo and Huancayo magnetic observatories as based upon magnetograms for all days

Year	Declination <i>D</i>	Inclination <i>I</i>	Intensity-components					Local mag- netic constant <i>G</i>
			Hor- izontal <i>H</i>	Total <i>F</i>	North- south <i>X</i>	East- west <i>Y</i>	Verti- cal <i>Z</i>	
<i>Watheroo Magnetic Observatory</i>								
	° ' "	° ' "	γ	γ	γ	γ	γ	
1934	3 47.8 W	64 20.1 S	24669	56960	24615	—1633	—51340	35603
1935	3 42.5	64 21.0	24672	56996	24621	—1596	—51379	35619
<i>Huancayo Magnetic Observatory</i>								
	° ' "	° ' "	γ	γ	γ	γ	γ	
1926	7 54.9 E	1 09.8 N	29666	29673	29383	4085	601	29667
1927	7 50.4	1 17.3	29659	29667	29382	4046	667	29661
1928	7 46.1	1 25.8	29646	29655	29374	4007	740	29648
1929	7 41.6	1 33.9	29636	29647	29369	3968	810	29639
1930	7 36.5	1 42.5	29614	29628	29354	3921	883	29618
1931	7 30.8	1 50.3	29624	29639	29369	3874	951	29628
1932	7 25.7	1 58.4	29617	29634	29368	3829	1021	29621
1933	7 21.4	2 04.7	29614	29633	29370	3792	1075	29618
1934	7 18.1	2 08.5	29622	29643	29382	3765	1107	29627
1935	7 15.2	2 11.2	29612	29634	29375	3738	1130	29618

## OCEANOGRAPHIC WORK

### REDUCTIONS OF CARNEGIE DATA

*Physical and chemical results*—Some final revisions of the manuscripts graphs, and maps giving the oceanographic data secured during the last cruise of the *Carnegie* and of discussions based thereon are being made before printing of the first two volumes of "Results of oceanographic and meteorological work on board the *Carnegie* on Cruise VII, 1928-1929." In this work the well-known oceanographer, Dr. H. U. Sverdrup, who is a Research Associate of the Institution, is giving some assistance.

## BIOLOGICAL RESULTS

Throughout the year Graham continued at the Hopkins Marine Station, Pacific Grove, California, his studies of the Dinoflagellata of the *Carnegie* plankton-collection. Mrs. N. Bronikovski was engaged for seven and a half months to assist in the routine examination of the plankton-samples and in the preliminary sketching of organisms. C. A. Dawson was engaged for some six weeks to assist in the preparation of drawings for publication. The generous cooperation of the Hopkins Marine Station, particularly of Dr. W. K. Fisher and Dr. T. Skogsberg, was extended as in previous years and was a material aid in the rapid progress reported.

The routine examination of the plankton-samples was completed for the southeastern Pacific and continued well into the mid-Pacific. This examination and sketching of contained organisms was done for 243 more samples; 1923 more working drawings were executed; 40 additional species were found.

A detailed study of the genus *Ceratocorys* was made and a paper on revision of the group was prepared. An account of this study was presented at the Seattle meeting in June 1936 of the Oceanic Society of the Pacific, Western Society of Naturalists, and American Association for the Advancement of Science. At this meeting Graham also was co-author in a communication on the oxygen-content of the Pacific with Moberg, Revelle, and R. H. Fleming of the Scripps Institution of Oceanography.

Good progress was made in the study of the Dinoflagellata. The searching of the samples, together with the mounting and sketching of organisms, was completed for the southeastern Pacific and carried well into the mid-Pacific to *Carnegie* oceanographic station 86. This phase of the work has now been completed for 518 samples. The number of mounts totals 1500; the collection of camera-lucida drawings now contains 5026 sketches; the number of species recorded to date is 320.

The material of the *Carnegie* collections permitted an intensive study of the genus *Ceratocorys*, a rare tropical genus of Dinoflagellates. The collections contained three new species of this genus. A detailed study was made of the thecal morphology of all the members of the genus. Thorough dissections were made of the entire skeleton, including the sulcal area, and complete series of drawings were prepared to illustrate all features. Studies were also completed of certain features of reproduction, variation, distribution, and correlation with hydrographic conditions.

Dr. P. L. Kramp of the Zoological Museum at Copenhagen, Denmark, has undertaken the identification and classification of the Medusa collected.

Dr. A. S. Campbell of Berkeley reports he has completed much of the work on the Tintinnioidea and now has in preparation his memoir discussing the results of his investigation.

## COOPERATION WITH BRITISH ADMIRALTY

The Department was privileged to continue cooperation with the British Admiralty as noted in last year's report in regard to the construction and equipment of the non-magnetic vessel *Research*. Following an invitation

received from the Board of the British Admiralty, arrangements were made by the Institution so that Peters could go to England to act as a consultant to the Admiralty in this matter. He has been in England since the end of September 1935. Various memoranda and details regarding instruments, methods of observation and practise at sea as developed on the *Carnegie* were prepared at the office and forwarded for the use of the Admiralty. Arrangements have also been made to determine the constants and corrections on International Magnetic Standards of a magnetometer-inductor of CIW type which has been ordered from the American manufacturer for use on the *Research*.

### INSTRUMENT-SHOP

As will be seen from the details given above in the reports of operations for the several sections of activity, many varied and difficult demands were made on the instrument-shop. These were promptly and skilfully met by C. Huff, in charge until his untimely death January 14, 1936, and by Steiner, who succeeded him in charge of the shop, and the other members of the personnel including Lorz, Haase, A. Smith, T. F. Huff, Malvin, and Mitchell.

Besides the perfection of the complex design and construction of the ionospheric apparatus for the experimental station at Kensington and of similar apparatus for the two observatories and for the cooperative work at the University of Alaska, the important task of improving and rebuilding the radio laboratory at Kensington was completed. Second in importance were the design and construction of experimental apparatus required in the research on and development of electromagnetic methods of measuring the Earth's magnetic field as reported above. Special mention may be made also of an audio-frequency oscillator and of a highly sensitive detector to test for the minutest amount of ferromagnetic impurities in castings and other materials to be used in electromagnetic measuring equipments; the new magnetic alloy Alnico was used with great advantage in this detector.

The shop shared in no small part in the improvement of the apparatus which made possible the successful measurements of air-conductivity on the second National Geographic Society—Army Air Corps Stratosphere Flight of the *Explorer II* and in the ground-station equipment used in connection therewith.

Matters pertaining to upkeep, maintenance, and improvements of buildings, building equipment, and grounds were responsibilities also looked after. The Institution's annual exhibit in December 1935 required considerable time of the shop-personnel, not only for the Department's contribution but also in giving assistance to other exhibitors.

### MISCELLANEOUS ACTIVITIES

*Communications to scientific organizations and universities*—Bartels lectured on application of statistical theory of periodical phenomena in a series on probabilities and fluctuations arranged for electrical engineers by the Technische Hochschule in Berlin, and gave two courses at the University of Berlin (1) on the application of mathematical statistics to geophysical and

meteorological observations and (2) on applied geophysics. He also described in a public meeting at the Forstliche Hochschule in Eberswalde, Germany, the various activities in research of the Carnegie Institution of Washington.

Active part was taken in American scientific societies through papers and discussions, including the Philosophical Society of Washington (before which Gish gave his presidential address "Electrical messages from the Earth: Their reception and interpretation"), the American Meteorological Society, and the American Physical Society at its meetings in Baltimore, New York, and Washington. Graham communicated results of the *Carnegie's* oceanographic work before meetings of the Oceanographic Society of the Pacific and the Western Society of Naturalists, and of the American Association for the Advancement of Science at Seattle.

Papers were presented before the New York and Washington meetings of the American Section of the International Union of Scientific Radiotelegraphy. The Department was well represented by papers at the annual meetings of the several sections of the American Geophysical Union; Fleming and Capello prepared for publication the *Transactions* of the Seventeenth Annual Meeting of that Union (two volumes containing 564 pages). Tuve gave one of three papers before the Science Forum of the New York Electrical Society in a symposium on heavy hydrogen and nuclear reactions.

Lectures were given at the University of North Carolina, Yale University, Johns Hopkins University, University of Michigan, and Cornell University, the majority of them in conferences on nuclear physics.

Tuve became a charter member in the newly formed Washington Academy of Medicine, which plans, as one of its principal objectives, to keep its members informed on developments of physics bearing on medical research and technique.

*Conferences and congresses*—Parkinson and Seaton represented the Institution and presented several papers at the Fifth Conference of Physicists and Astronomers held at Sydney, Australia, May 25 to 28, 1936. While it was not possible to have representatives attend the meeting of the Commission of Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization at Warsaw in September 1935, proposals and suggestions were submitted in a 12-page planographed circular; these evoked much discussion and consideration. Bartels took part in several conferences in Germany, including one in collaboration between physicists and geophysicists at Frankfort am Main. Communications on work of the Department, particularly that relating to ionospheric research, were prepared for the Pan-American Scientific Congress meeting in Mexico City in September 1935. A paper on "Earth physics and geographical progress" was prepared for the meeting of the Pan-American Institute of Geography and History held October 1935 in Washington.

Other important conferences in which the Department took part are noted elsewhere in this report.

*Exhibits*—An exhibit on the natural electric currents in the Earth's crust was prepared for the annual meeting of the Institution. With information acquired in recent years, it was possible to view the broader aspects of the

electric currents which circulate in the Earth as described elsewhere in this report.

A display to illustrate instruments for use in field and at observatories, methods, and the results of magnetic observations in polar regions, obtained in cooperation of the Department with the Second Byrd Antarctic Expedition, was prepared for the Texas Centenary Exhibition at Dallas.

An exhibit of air-conductivity apparatus and results obtained in the stratosphere was displayed at the Washington meeting of the American Physical Society.

A world-map depicting the operations of the Department since its formation in April 1904 was completed and copies were supplied for the exhibit at the Peace Palace at the Hague in celebration of the 100th anniversary of Andrew Carnegie's birth.

*Public progress-reports*—Cooperating with Editor Bunker, material for 12 clip-sheets and two news-service bulletins was supplied. From time to time counsel was given various writers for newspapers and magazines in the preparation of articles on scientific work.

*Staff-meetings and colloquia*—Eighteen afternoon biweekly staff-meetings were held during September 20, 1935, to June 12, 1936, there being presented at each, by invited guests and staff members, some topic pertaining to research in the Department's fields. These meetings stimulated and encouraged cooperation between the Department and other organizations in Washington. Some 30 evening meetings of a seminar on upper atmospheric investigations were held in the library of the Department. Ten members of the staff took part in this seminar, which included lectures on basic physical theories involved and instrumental developments and technique. Members of personnel attended many of the weekly morning staff-meetings of the National Bureau of Standards and the weekly evening meetings of the Washington Physics Colloquium; they were well represented in both by papers presented.

*Cooperation with Division of Historical Research*—Members of the Division of Historical Research were instructed in the methods of astronomical observation and in the use of radio-receiving equipment. Astronomical observations obtained in Yucatan by the Division were checked.

*Library*—The library continued to acquire through purchase or exchange practically all new publications dealing with terrestrial magnetism and electricity. Accessions during the report-year were 673; the total number of accessioned books and pamphlets is now 23,542. The practise of carding, classifying, and filing in the library-index was continued for all important articles on terrestrial magnetism and electricity and on other subjects of immediate or potential interest to the Department as published in some 100 scientific journals which are regularly received. Thus the new accessions represent only a small part of the additions to our index and in no way indicate its increased value as a reference-tool for those using the library.

Librarian Harradon continued to take an active part in editing contributions to the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, particularly the manuscripts in foreign languages. Abstracts, notes, and



annotated lists of recent publications were prepared for each quarterly issue of that Journal. He also translated many articles, documents, and letters. Among these, special mention may be made of communications pertaining to international scientific meetings.

The material in the library was consulted by investigators and students from various institutions and governmental bureaus. The cordial and reciprocal relations with other libraries, particularly the Library of Congress, were maintained to the mutual advantage of all concerned.

The list of contributions by the members of the Department's staff since 1904 compiled by the librarian shows a total of 1472 such publications through the year 1935. In the distribution of the reprints of these papers to institutions and correspondents in foreign countries, advantage was again taken of the facilities of the International Exchange of the Smithsonian Institution, thereby economizing time and expense.

Besides stenographic work on difficult manuscripts and reports and maintenance of correspondence files, Dove looked after the distribution of reprints and prepared for the binder the "Contributions" of the Department for 1935.

*Office administration*—The continually increasing amount of correspondence, of auditing of accounts, of preparation of reports and manuscripts, and of other innumerable matters of office management were handled efficiently by M. B. Smith, chief clerk, and his assistants Moats and Singer. Capello's services as secretary and property clerk and particularly in the preparation of manuscripts for publication were unusually excellent. Hendrix, in addition to his computing duties, was responsible for many excellent drawings required to illustrate articles published on investigations and to illustrate the manuscripts for several volumes of Department *Researches* (1) on results at the Watheroo and Huancayo observatories and (2) on the oceanographic results—physical, chemical, and biological—obtained during the last cruise of the *Carnegie*.

*Bibliography*—A list of the published contributions of investigators and research associates during July 1, 1935, to June 30, 1936, is given in the report of the Institution's Division of Publications.

## ARCHÆOLOGY

**Caso, Alfonso**, Mexico City, Mexico. *Continuation of archæological and historical studies in the region of Oaxaca, Mexico.*

During the past year, which witnessed the fifth season of work at Monte Alban, under the direction of Dr. Caso, these studies were aided by grants from the Carnegie Institution of Washington, representing in part funds made available for the purpose by the Carnegie Corporation of New York. This program has also been undertaken through cooperation of the Pan American Institute of Geography and History. Dr. Caso was assisted in his work by Srs. Acosta, Bazán, Dautermann, Romero and Valenzuela.

Operations were begun on April 1 and carried on until May 2. The general program of exploration, excavation and reconstruction was continued and resulted in the completion of a large body of work begun in previous years and in the opening of new mounds and new areas of great importance. In spite of the shortness of the field season, the results were gratifying in the extreme.

Probably of major importance is the discovery of a large amount of hieroglyphic text. Due to the wealth of material of this sort, the inscriptions of Monte Alban may now be divided into three periods and these periods be correlated with the ceramic periods of the site. Working through hieroglyphics and other sculptural material, it is now possible to say that the very early culture at Monte Alban known as that of the "Danzantes" is definitely an archaic Zapotecan culture and that the *tonalamatl*, or sacred calendar of Middle America, was in use at that early period. In so far as the second period at Monte Alban appears to have connections with the so-called Q Complex, a complex of traits found elsewhere under conditions that seem pre-Maya, it is apparent that the *tonalamatl* is very ancient at Monte Alban and probably antedates the Maya *tzolkin*. Further information in regard to the Zapotecan calendar comes from a magnificent carving in alabaster, known as the Lápida de Bazán, which is not only the finest example of sculpture yet discovered at Monte Alban, but which possesses sixteen hieroglyphics that apparently list in order the months of the Zapotecan year. The extensive body of inscriptional material recovered this year includes hieroglyphs of the days and months, and provides us with a list of place names and related dates that may show the conquests of Monte Alban and the time of these conquests.

Leaving the highly important hieroglyphic and calendrical material, it should be noted that work at a certain Mound J has brought forth the fact that the structure is probably an astronomical observatory of a form previously unknown in Middle America. Another find of specific importance is the recovery from the stair platform of Mound B of four pieces of carved jade that are among the finest examples yet discovered in Mexico. These pieces come from the third and fourth periods at Monte Alban.

A considerable amount of excavation was done during the past season in connection with tombs and burials, and this work promises to be of great value in determining foreign cultural contacts and establishing a

relative chronology as between cultures. Worthy of specific mention is the discovery of a Teotihuacan vase and of a thin, stone effigy ax head of a type sometimes known as a compressed head. The occurrence of vase supports in Period 2 seems to connect this culture with the Q Complex. The practise of placing offerings beneath stelæ suggests cultural connections with the Maya. A trephined skull and another with worked teeth are of cultural significance. Lastly, it should be noted that the stratigraphical work definitely confirms the classification of Monte Alban ceramics in five periods, the fifth being that of the Mixtec occupation, and that similar work among the mounds and buildings allows us to relate their periods of construction with the previously established ceramic periods.

## BIOLOGY

**Castle, W. E.**, Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-34.)

In February 1936 it became necessary to bring to a conclusion the investigations of mammalian genetics which, for many years, have been conducted at The Bussey Institution under the joint auspices of The Carnegie Institution of Washington and Harvard University. Consequently this report will deal with such results of the work as had, up to that time, been secured.

The most important of these has come from a study of size inheritance in mouse crosses, a subject on which a preliminary report was made last year. By using as parent stocks races of mice long inbred, and so of high genetic uniformity, and by rearing large numbers of offspring under conditions carefully standardized and on a uniform diet, it has been possible to discover and to measure the influence exerted by various mutant genes on body size. The genes studied were previously known to affect coat color or other morphological characters but not body size, which was supposed to be controlled by special genes borne, at least in one case, that of brown pigmentation, in the same chromosome as the brown gene.

What we have been able to demonstrate is that the size effect is not due to a special size gene linked with the brown gene, but to the physiological action of the brown gene itself which, accordingly, is a "size" gene in addition to, or perhaps because of, its action in producing brown rather than black pigment, or possibly because its primary effect precedes the production of pigment altogether, both brown pigmentation and increased body size being secondary effects. Further investigation thus becomes desirable of the time and method of operation of such genes.

We find also that the blue (dilute) color mutation, as well as the brown mutation, acts as an accelerator of general body growth. Dr. C. V. Green, who first discovered indications of such a relationship, supposed that the accelerating action was due to a "size" gene borne in the same chromosome as the dilution gene. This interpretation we have shown to be erroneous by the results of a cross involving simultaneously a gene "short ear," which is closely linked with dilution, and which has a contrary effect, retarding rather than accelerating general body growth. When dilution and short ear are introduced into a cross together, and recovered by backcrosses respectively to (1) a dilute race (not short eared) and (2) a dilute race also short eared, it is found that dilution alone *increases* body size by about 2 per cent, but that short ear, even when associated with dilution *decreases* body size by about 4 per cent. The retarding effect of short ear thus more than offsets the accelerating effect of dilution, when both are operative simultaneously. These contrary effects on size can not be due to specific size genes linked respectively with dilution and short ear, since dilution and short ear are closely linked with each other, crossovers occurring less than once in a thousand times.

We find that the mutant gene pink eye, like short ear, acts as a retarder of general body growth, but to a less extent. This effect is noted even when pink eye and short ear are introduced to a cross by the larger parent race, a condition under which the hypothesis of specific size genes linked with pink eye and short ear, respectively, would demand increased rather than decreased body size in pink-eyed or short-eared segregates.

As to the time of action of these genes in development, we have certain interesting indications. Dilution has a *lesser* effect than the brown gene as an accelerator of growth in four different backcrosses in which both were simultaneously involved, if size is estimated either by adult body weight or by body length. But as regards a different body dimension, tail length, dilution has a *greater* accelerating effect than brown in four different backcrosses. This indicates that the dilution gene, in addition to a moderate accelerating effect on general body growth, has a special local accelerating effect on growth of the tail. Just when in development this influence is exerted remains, for the present, undetermined.

As to the short ear gene, its major influence as a retarder of growth is manifested in the reduced size of the ears, as indicated by the name given to this gene. Its chief action would thus seem to be localized at the opposite end of the body from the special field of action of the dilution gene with which it is closely linked genetically. The time of its manifest action is post natal and prior to age three weeks (weaning).

It is doubtful whether specific size genes exist, of the sort assumed in current explanations of size inheritance. Variations in body size, so far as genetically determined, would seem to be incidental consequences of biochemical processes controlled by, or at least influenced by, genes borne in the chromosomes.

As regards the rabbit investigations, which have occupied a major portion of my time in recent years, it has been necessary to terminate them abruptly and prepare for publication such conclusions as were deducible from them. In a further study of linkage between two genes for rex (short) coat,  $r_1$  and  $r_2$ , a population of 384 individuals was produced by backcrossing normal coated  $F_1$  females to double recessive males. The indicated crossover percentage has been found to be 17.2 per cent in females. In  $F_1$  males it would probably be found to be somewhat smaller, as it had been indicated to be also by an earlier study of an  $F_2$  population.

The first case in mammals of linkage involving three genes located in the same chromosome and suitable for a study of interference has been brought to a conclusion with the rearing of a backcross population of 908 individuals classified simultaneously as regards Himalayan albinism, yellow fat, and brown pigmentation. The order of the genes is *CYB*, the crossover percentage between *C* and *Y* is, for females,  $14.4 \pm 0.8$ ; for males,  $8.2 \pm 1.7$ ; between *Y* and *B* it is, for females,  $28.4 \pm 1.0$ ; for males,  $26.6 \pm 2.8$ . Crossing over is thus seen to be probably more frequent in females than in males, as we have previously shown it to be also in mice and rats. Interference is clearly shown by the observation in both sexes of fewer double crossovers than would be expected as a chance occurrence.

A study of the inheritance and linkage relations of the new hair mutation "satin," mentioned in my last report, shows it to be a recessive mutation located in some chromosome other than the X-Y pair, and the autosomes which contain the following genes:  $rex_1$ ,  $rex_2$ ,  $furless$ ,  $English$ ,  $albinism$ , and the blood group gene  $H_1$ .

The uncompleted program involving tests for possible linkage with dilution, Vienna white, dwarf, and brachydactyl has been taken over by Dr. P. B. Sawin, who hopes to complete it at Brown University, where he will also maintain, for the present, certain of our other rabbit stocks important for investigations of rabbit genetics but not obtainable elsewhere.

In the investigations with mice and rabbits I have had as Research Assistants Dr. S. C. Reed, who will next year conduct investigations of animal genetics at McGill University, and Mr. L. W. Law, who will shortly transfer his uncompleted work to the Biological Laboratories in Cambridge. Dr. C. E. Keeler has continued his investigations of mouse genetics and of the blood groups of rabbits, from which further important results may be expected.

**Conger, Paul**, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of studies on Diatomaceæ.* (For previous reports see Year Books Nos. 18-34.)

A continuation of studies on diatoms of the Atlantic Coast of North America, and on various morphological and ecological problems concerning them, constituted the main line of research of this laboratory during the past year. Additional material was collected from Chesapeake Bay during the summer, over a period of six weeks while carrying on diatom investigations at the Chesapeake Biological Laboratory.

Also, while at the above laboratory, a course on diatoms was offered, as in several previous summers, including lectures, laboratory, and field work, for which four graduate students were registered.

Following this a month was spent in Wisconsin, in cooperation with Dr. Birge and Dr. Juday, and associates of the University of Wisconsin, and the Wisconsin Geological and Natural History Survey, at their laboratories at Trout Lake in the north central part of the state. Attention was devoted to a study of the diatoms of the region and certain problems connected with them. These laboratories are located in the heart of the lake district, and it was possible with available facilities to visit and make extensive collections, numbering 130 samples, from 40 lakes of widely differing chemical and biological conditions. Circumstances at the Trout Lake laboratories afford particularly favorable opportunity for the study of certain diatom problems in the advantages offered of close cooperation with physicists, chemists, bacteriologists, and biologists engaged in fishery investigation, and in access to the very complete records of chemical analyses of more than 500 lakes made by Doctors Birge and Juday, and their staff over a period of many years. A wide variety of conditions is found in the different lakes easily accessible to the laboratory. But with climatic and water conditions otherwise very favorable for diatom growth in this region, it is found, however, that the abundance of diatoms is greatly restricted, due

to deficiency of nutritive materials in the water of many of the lakes. This affords favorable opportunity for both observational and experimental studies of factors influencing their abundance and succession. Another interesting aspect of the situation here is the occurrence of quite different groups of diatoms in closely adjacent lakes of apparently highly similar conditions. Much of this material has been prepared for study, and more detailed studies of these problems are in progress.

During the Fall an exhibit was prepared, as part of the annual exhibit of the Carnegie Institution in December, stressing the subject of variation in diatoms, its causes and importance, with slides to show a number of interesting points in this subject not previously demonstrated.

Final arrangements were made by Mrs. Jennie F. Mann, for the gift of Dr. Mann's personal diatom collection of several thousand slides, and much material, collected from all parts of the world over a period of nearly fifty years, to the Carnegie Institution of Washington; and the gift was formally accepted by the President and Trustees of the Institution, the collection to be known as "The Albert Mann Diatom Collection." A list of the materials was made, and it is gratifying to know that this fine collection will be kept intact, and will remain as a memorial to the long and careful work of Dr. Mann, in the Institution which made possible the first concentrated effort in the field in this country.

A list of Dr. Mann's published papers was prepared, and this together with biographical notes were furnished to the editor of the National Cyclopaedia of American Biography at the latter's request.

A collection of 38 slides in duplicate, representing deposits in many different parts of the world, was received for our collections from Mr. J. R. Bartholomew of New York.

Through a cooperative arrangement with an English diatomist, who visited the Island of Barbados during the early part of the year, for the purpose of making a thorough examination of the extensive deposits there, it was possible to secure for our collections portions of all the material collected by him, about 40 samples in all. This is probably the finest collection of material we have been able to obtain from this region, and most of the material has been prepared for study.

Cooperation was given Dr. Paul S. Galtsoff and associates of the U. S. Bureau of Fisheries in identification of diatoms in connection with their studies on pollution of the York River, Virginia.

The usual numerous requests for information regarding diatoms and associated problems were answered during the course of the year, including more extensive information given the Johns Manville Corporation and the American Diatomite Company. At the invitation of the latter a week was spent at their deposits and plant in Florida, looking over their operations and in consultation with them regarding some of their technical problems. This gave opportunity at the same time for investigation of certain scientific aspects of the deposits there.

A talk on the importance of diatoms in marine biology was given before the class in Aquiculture at the University of Maryland, as an introduction to their study of this phase of the subject.

Two new methods for the examination of diatoms, especially adapted to revealing the structure of hitherto difficult species, were developed during the year and it is hoped will be ready for early publication.

An article was published in *Science*, for May 29, 1936, on a method new in this field, and proving very useful, entitled "The Use of Hollow Ground Slides made with the Dental Engine." This was supplementary to an article on the general use of such slides by Dr. Marshall Hertig in an earlier issue of *Science*. The present article, in addition to applying the method independently in diatom research, discusses technical difficulties involved, tests the method for efficiency, and describes a new tool for preparation of the slides. Attention might be called to a particular feature of this paper, of what is probably a new use of diatoms, to test, not a lens or a scientific fact, as has previously been done, but a method.

A section on the diatoms, was also prepared to be incorporated in an article by Captain Robert Bartlett and others, on the recent Bartlett Expeditions to Greenland for scientific investigations. The scientific material for this article is being assembled by Dr. Waldo L. Schmitt of the National Museum.

**Dice, Lee R.,** University of Michigan. *Studies of the ecology and genetics of North American mammals.* (For previous reports see Year Books Nos. 31-34.)

Most of the summer of 1935 was employed in a study of the populations of small mammals, with the hope that ultimately a determination of the total populations of some races and species could be secured. The early part of the period between July 19 and September 11, 1935, was spent in the sandhills of western Nebraska and the latter part of the period in the Black Hills of South Dakota. In the sandhills mammals of all kinds were very scarce, perhaps as a result of the severe drouth of previous years, while in the Black Hills they were apparently present in nearly normal numbers. Much attention was given to experiments on methods of determining the abundance of small mammals in the various types of habitats. Although no satisfactory technique for determining the numbers of any species in a given area has been worked out, it is believed that the information secured may give a basis for a very rough estimation of the total population of the subspecies *Peromyscus maniculatus nebrascensis*, which is limited in distribution to the sandhills, and perhaps also of the local race of *P. m. osgoodi* inhabiting the Black Hills.

In connection with the studies of mammal populations and their fluctuations, a study of the breeding rate, length of the breeding season, and individual range of the white-footed mouse, *Peromyscus leucopus noveboracensis*, is being conducted near Ann Arbor, Michigan, by W. H. Burt. Frank H. Clark is conducting a laboratory study of the age at sexual maturity of various species and races of *Peromyscus*. It is expected as a result of these studies that a calculation of the average rate of multiplication of these mice per generation and per year can be made for certain regions.

Burton T. Ostenson assisted by Palmer Sime spent the period from July 8 to August 26, 1935, in an ecological study of the mammals of the Nebraska



sandhills. One transect was carried across the western edge of the sandhills into eastern Wyoming and another transect was carried across the southeastern edge of the sandhills into eastern Nebraska. The habitat relations of the mammals were studied at Lincoln, Ravenna, Dickens, Kennedy, Antioch, Hay Springs, and Agate in Nebraska, and at Ayers Park in Wyoming. Breeding stocks of deer-mice for variability studies were also collected at these localities. In general the ranges of the sandhills subspecies of mammals are closely restricted to the sandhills.

In completing, with the help of Philip Blossom, the report on the ecology of the small mammals of parts of Arizona and Sonora it is discovered that the tendency for the pelage colors of the mammals to be correlated with the soil color of their habitat holds not only for the various isolated desert mountains and lava beds, but also for the various life belts of the mountains and plains. On the upper forested parts of the mountains where the soil is dark in color the small mammals have dark-colored pelage, while on the pale-colored soils of the desert plain the small mammals have pale colors. The studies in Arizona are being continued by Philip Blossom.

Considerable progress has been made in the studies of fertility relationships in the genus *Peromyscus*. The two species, *Peromyscus leucopus* and *P. gossypinus*, making up the *Peromyscus leucopus* group of mice, and all their subspecies seem to be completely inter-fertile, and both sexes of the hybrids also are fertile. On the contrary, in a joint study with Margaret Liebe, it is shown that there is partial infertility between the two forms, *Peromyscus truei truei* and *P. nasutus griseus*, both of which are members of the *P. truei* group. Matings between these two forms are less successful than matings between the members of either form. The female hybrids between the two forms are fertile, but the male hybrids are sterile. The sterility of the male hybrids is due to their failure to produce spermatozoa. This partial infertility is believed to indicate a stage in speciation. Studies of the fertility relationships between other closely related forms of *Peromyscus* are being continued by Margaret Liebe.

In connection with the studies of variability of the mice of the genus *Peromyscus*, new breeding stocks have been added this year to those at the Laboratory of Vertebrate Genetics, University of Michigan, of *bairdii*, *nebrascensis*, *osgoodi*, *ozarkiarum*, *noveboracensis*, *truei*, and *nasutus*, coming from the states of Michigan, Nebraska, New Mexico, Oklahoma, South Dakota, and Wyoming. The number of laboratory-reared mice prepared for specimens during the past year is 2274.

In a study of the variability of 17 stocks of the white-footed mouse, *Peromyscus leucopus noveboracensis*, from the north-central United States, it has been discovered that this species differs from the deer-mouse, *Peromyscus maniculatus*, in not exhibiting any appreciable growth in body dimensions after the first year of life. There is much local variation in all the characters of the white-footed mouse, and the mice from closely adjacent wood-lots may differ greatly in body dimensions and in pelage color. On the contrary, there is no strong geographic trend in the characters of these mice over the area covered by the study.

A new graphic method for statistically comparing a number of sets of measurements has been developed with the aid of Harold J. Leraas. The method is of particular value when a large number of means are to be compared statistically.

A new recessive character in the deer-mouse has been discovered by Frank H. Clark. The presence of this character causes a loss of the postjuvenile pelage with consequent nakedness at that age, but the juvenile and adult pelages are very little affected.

In a study of linkage in the deer-mouse conducted by Dr. Clark, the characters albinism and pink-eye (pallid) have been found to be closely linked, confirming a previous study by Sumner, and the crossover percentage between these characters shown by 221 young is 12.0 in the males and 18.7 in the females. Other linkage tests indicate that yellow coat color is not linked with albinism or hairless. The independence of albinism and hairless, first reported by Sumner, has also been substantiated. Dilution, another character affecting the color of the pelage, shows independent inheritance from both yellow and albinism.

A black-eyed white or cream mutation in the meadow-mouse, *Microtus pennsylvanicus*, has been studied by Dr. Clark. It is similar in appearance to cream in the black rat (*Rattus rattus*) and behaves genetically as a simple recessive character.

From a study on a sloping plane of young *Peromyscus* of various races and species, Dr. Clark finds a correlation between the angle of slope at which the mice climb and their climbing habits in nature. Semi-arboreal races and species climb at a greater angle with the horizontal than the more terrestrial forms, and are able to orient to gravity at a lesser slope of the plane on which they are placed.

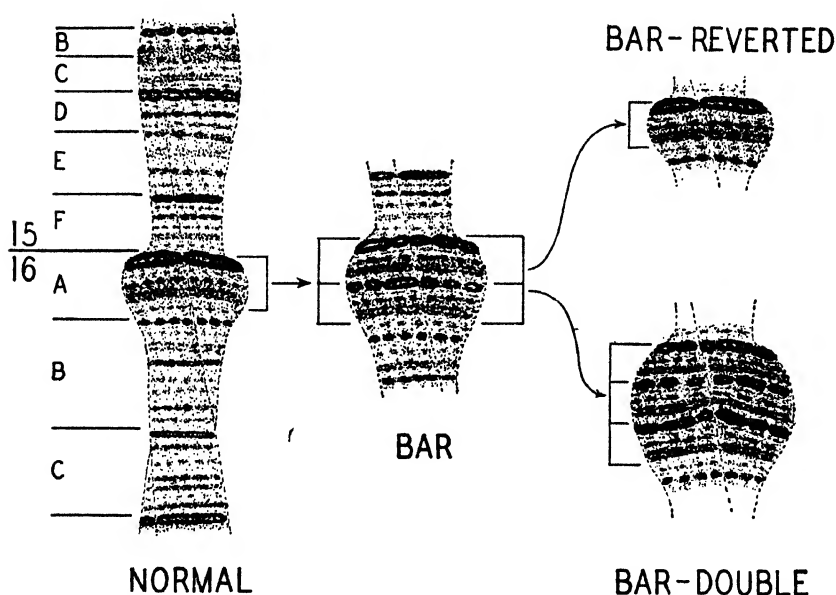
By a study of vaginal smears Dr. Clark has determined that the estrous cycle of the cotton-rat, *Sigmodon hispidus*, has an average periodicity of 8 days.

**Morgan, T. H., C. B. Bridges and Jack Schultz**, California Institute of Technology, Pasadena, California. *Constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15-34.)

During the past two years the emphasis in the *Drosophila* work has shifted from analysis by breeding methods to analysis by cytological observations. Before the importance of the salivary chromosomes was pointed out by Painter, more could be learned about the structure and behavior of chromosomes by "counting flies" than by looking at the chromosomes themselves. Genetic analysis forged far ahead of cytological checking. It was this sound genetic foundation, however, giving the serial order of the genes and their approximate locations within the chromosomes, which lent meaning to the seriation of bands along the salivary chromosomes.

The salivary maps (Bridges, Jour. Hered., Feb. 1935) have been indispensable in this type of work. But they have become inadequate, although correct so far as they go. Fully half again as many bands will be shown in the revision of the maps which is being made, and also the relative intensities are more carefully described.

The correspondences between the banding of the salivary chromosomes and the loci on the genetic maps have been investigated in considerable detail by Bridges for the right end of chromosome 2R. To date, the breakage points of five inversions, two translocations and six deficiencies have been established within the short section from the locus "humpy" to the tip of 2R. One striking result of this study is that the chromosomes vary not only in their "coefficient of crossing over" (ratio of map distance to corresponding salivary length), but also in their "coefficient of mutation" (ratio of number of mutants to length of salivary chromosome carrying them). These coefficients vary independently of each other. For example, the map section of seven units from plexus to the tip of 2R has about the same number of bands (length of salivary chromosome) as the section of seven units from



humpy to plexus, and hence has the same coefficient of crossing-over. But the px-tip section has over five times as many mutants as the equally long hy-px section, hence has five times as high a coefficient of mutation. The low coefficient of mutation for the hy-px section (and of similar sections elsewhere) is accounted for partly, or in full, on the hypothesis that this is a region rich in duplications, some of which have been observed. The presence of duplications in the wild-type chromosome results in a buffering action, so that if recessive mutations occur they are unable to come to expression or do so only after further changes have occurred.

The chromosome structure of the Bar mutant was one of the first problems attacked by the salivary method in our laboratory. Work on Bar, started in January 1934 by Bridges, continued with increasing precision for two

years before it resulted in a complete and satisfactory analysis, which agrees essentially with that made independently by Muller. Comparison of the salivary X-chromosome carrying Bar with that of normal non-Bar flies showed an extra section of bands present in excess of the normal complement, thus forming a duplication. The section duplicated lies not far from the base of the X, in the bulbous "turnip" segment, subsection 16A according to the standard maps of Bridges (see figure). The repeated series consists of a very heavy doublet, a very faint singlet, a medium singlet, and a medium more diffuse close doublet, totaling six distinguishable cross-lines. The two identical series lie in the same order, in tandem, not in reversed sequence. The original production of the Bar duplication might accordingly have been through a rare unequal crossing-over, whereby the given short sections from the two different parental strands got into the same emerging crossover strand. The dominant phenotypic effects of the Bar mutant are attributable to this duplication of genes, which may act in one or both of two ways, namely by increasing the effectiveness of the genes doubled (quantitative action in genic balance) or by lowering the effective interaction of the adjacent genes through wedging them farther apart (position effect in genic balance).

The Bar stock was long ago found by Zeleny to give spontaneously occasional reversions to wild-type, and also, vice versa, to a more extreme Bar. These changes were interpreted by Sturtevant and Morgan as loss and doubling of the Bar gene through "unequal crossing-over." Salivary analysis of the Bar-reverted and of the Bar-double phenotypes has now confirmed this hypothesis. Bar-reverted was found identical with wild-type, having lost the duplication. Bar-double was found to have this section still again, in triplicate (see figure).

Direct observation of a position effect was made in noting that in Bar-double all three sections become irregular in arrangement and broken, while the whole region becomes rounded up, presumably because of the synaptic attraction of homologous bands along the chromosome strands and obliquely from series one of one strand to series three of the other.

Further cytological support of the position effects of the Bar region came from salivary analysis by Bridges of the "Baroid" translocation found and analyzed genetically by Dobzhansky. Dobzhansky interpreted the Bar-eye effect present in this translocation as due to the separation of genes at or near the Bar locus, and the bringing of genes from chromosome 2 into juxtaposition with these separated genes. The new interaction between the genes in the X-chromosome and in the second chromosome was held responsible for the Bar-like effect. Salivary analysis of Baroid showed that the break in the X does come in the Bar region—in fact between the halves of the heavy doublet of 16A1. The break in 2R is in 48C, to the right of the heavy doublet and also one of two faint lines following it. Incidentally, the Baroid translocation was found to be further complicated, by what is apparently a small inversion extending from 41A to 47A.

The demonstration of duplications (direct or reversed "repeats") as parts of the *normal* chromosome makeup of the wild species had been established by Bridges (Jour. Heredity, Feb. 1935) through direct examination of the salivary banding and synapsis relations. Subsequent work has now shown

that such "repeats" are very numerous. The locations of many of them will be indicated on the standard salivary maps now under revision. Duplications probably constitute the main method by which the number of genes available to this species has been increased in the evolutionary process. One method of origination of duplications is by unequal crossing-over, as just shown in the case of Bar and Bar-double. Another method has also been demonstrated—that of crossing-over between semihomologous inversions. For example, the two inversions  $\text{In}(2\text{L})\text{Cy}$  and  $\text{In}(2\text{L})\text{T}$  had been studied genetically and found to give practically no suppression of crossing-over in the double heterozygote. But they produced certain inequalities in the viability of the complementary crossover classes, which were interpreted by Bridges as due to deficiencies and duplications brought into existence by crossing-over between inversions which did not exactly match. Salivary analysis by Bridges and Li has confirmed slight differences in the positions of the breakage points of these inversions. In  $\text{In}(2\text{L})\text{Cy}$  the left break point is quite near the tip of 2L, just to the right of doublet 22D1. The right break point is about two-thirds of the distance toward the base of 2L, at the end of 33F. The break points of  $\text{In}(2\text{L})\text{T}$  follow 22D3 and 34A8. Thus, there is a difference of two lines between the left breaks and eight between the right breaks. Crossovers in the double heterozygote should be of two types—one deficient for both these differences and the other a duplication for both these differences.

In collaboration with Dr. J. C. Li of Yenching University, Peiping, Bridges has undertaken an analysis of the inversions in all of the salivary chromosomes, especially those in daily use as balancers. The inversions in the X have already been worked out roughly by others, hence the inversions in the second chromosome were made the first point of attack.

The most used second chromosome balancer is the Curly mutation with its associated left and right limb inversions, *viz.*  $\text{In}(2\text{L})\text{Cy}$  and  $\text{In}(2\text{R})\text{Cy}$ . One break point of  $\text{In}(2\text{L})\text{Cy}$  was found to be near the left tip of 2L following line 22D1 and the other is about two-thirds of the distance toward the base, following subsection 33F. The right inversion is very long. Its left break lies very close to the base of 2R, in section 42A, following the heavy capsular doublet, the very faint, and the faint, lines there (42A4). The right break is seven-eighths of the distance toward the tip, following the two heavy lines of 58A and preceding the strong doublet of 58B1.

A 2L-inversion, isolated by Bridges from experiments involving "threeple" stock (under the names C23 and C231) and also isolated by Sturtevant from the threeple stock itself (under the name C2LT) proved to be identical cytologically with a 2L inversion found later by Helen Redfield (listed as  $\text{In}(2\text{L})\text{HR}$ ). The break points of this inversion, which may be called  $\text{In}(2\text{L})\text{T}$ , are very closely similar but not identical with those of  $\text{In}(2\text{L})\text{Cy}$ , being after 22D3 (instead of 22D1) and after 34A8 (instead of to the left of 34A1).

The first suppressors of crossing-over found for chromosome 2 were Sturtevant's Nova-Scotia inversions, namely,  $\text{In}(2\text{L})\text{NS}$  and  $\text{In}(2\text{R})\text{NS}$ . Salivary analysis now shows that  $\text{In}(2\text{L})\text{NS}$  is about the same length as  $\text{In}(2\text{L})\text{Cy}$ , but is situated farther toward the base of 2L. Its left break point is apparently in 23E, following the fairly strong doublet E1 and the light

line 23E2, and preceding the last faint doublet of 23E. Its right break point is in 35F, apparently immediately following the strong doublet of 35F1.

Inversion-(2R)NS is relatively short and far out from the base of 2R. The break points are in 52A, apparently at the end of 52A, and in 56F following the group of four heavy doublets, and probably also the first of the three medium doublets of 56F.

There have been found three very similar inversions, each involving the production of a dominant character. All three cut through the "inert" region of 2L and are characterized by mottling of the eyes. The first is "Upturned" wings, found by Ball and analyzed by Bridges and Li. The salivaries show one break near the middle of 2R, at the end of 53A. The other break is to the left of the spindle attachment and also of one or two of the coarse doublets there. In other words practically all of the left limb has been exchanged for the outer half of 2R. The second is "Revolvute" wings, found by Dobzhansky and analyzed by Schultz, Bridges and Li. The inverted middle section is somewhat shorter than in the case of Upturned. The right break follows the pair of fairly strong close doublets 52D1 and 52D2. The left break seems to be exactly contiguous to the spindle attachment and to the left of it. The third case, "Revolvutoid" wings, resembles Revolvute phenotypically and genetically, but has not yet been examined cytologically. Its chief interest is in that it was found as a single homozygous female in a pair culture in which no heterozygotes occurred.

The second-chromosome dominant Glazed (DIS-4:33, Austin stock No. 227) was known to be accompanied by an inversion involving both left and right limbs. Salivary analysis shows it to be the reciprocal exchange of the outer third of 2L with the outer half of 2R. The breaking points are at the ends of 27E and 51D.

The third-chromosome inversions have been studied by Bridges and a more precise analysis by Bridges and Li is under way. Inversion-C3, with lethal-3a, was the first suppressor of crossing-over found in *Drosophila*. It is apparently a strictly terminal inversion, the break following 94E1. This is interesting in view of the reasons advanced by Muller for supposing that a one-break inversion of the end of a chromosome could not occur. The Payne inversions have their breaks as follows: In(3L)P has its left break following 64B1 and its right break following the doublet of 72E1. In(3R)P is a short inversion having its right break near the end of 96A but preceding the three last lines of that subsection. The left break follows the 89C1 doublet. In(3R)Missouri, found by Sturtevant, is a short inversion far out toward the end of 3R. Its left break point precedes the 93E1 doublet and follows the 98F1 heavy doublet.

It has been found that about a tenth of our stocks are carrying some inversion or other. The most frequent of these is 3R-Payne, then 2R-Cy, but others are known.

Translocation-(2,3)S<sup>M</sup>Cy, sent to us by Muller and used as a balancer, was produced originally by X-raying the Cy inversions. The translocation consists in the reciprocal exchange of the very short tip of 2L, beyond the inversion, with nearly all of 3L. The breaking points follow the large capsule of 21E and the large capsule of 79D.

Translocation-(2,3) Xasta, sent to us from Moscow, had been analyzed by Sturtevant as containing In(2R)Cy and In(3R)Payne and a reciprocal translocation involving 2R and 3R. Salivary analysis confirmed the presence of In(2R)Cy and In(3R)P and showed that the translocation has break points very near but not identical with two of the inversion points. The break in 2R occurred just basal to the 2R-Cy inversion, apparently at the end of 41F and to the left of the big capsular doublet of 42A1. The break in 3R occurred within the Payne inversion, very close to the outer end of the inverted region. The break follows the double offset capsules of 89D and two other bands, i.e. after 89D4.

Schultz has continued his study of the variegated types of *Drosophila*. He had suggested that this variegation resulted from the loss of small sections of chromosome, following translocation to heterochromatic regions. This assumption is now proved for two particularly favorable cases. Both show variegation for the loci white and split-Notch. In the salivary gland cells, chromosomes deficient for the section carrying Notch are found along with cells carrying the full chromosome complement. The X-4 translocation which has been most studied (variegation for the loci white, split, Notch and diminished; the translocation itself is an exchange of the end of X, to 3E1, for sections 101 F and 102 of 4) generally has lost a section of 18 bands from 3B3 to 3E1; however, the amount lost is not always the same. The portion closest to the heterochromatic region is always eliminated, if any loss has occurred; the variations in size of piece lost therefore concern the effective distance from the heterochromatin necessary for variegation to occur. This agrees with the genetic data: the greatest frequency of variegation is shown for genes close to the point of translocation, with a decrease for the genes farther away.

This loss of small sections of chromosome occurs to a different extent in different tissues. In the germ cells, the frequency is negligible in most variegated types. For the white variegations, it is possible to study the frequency in the malpighian tubules. Cell counts were made of the white and yellow cells in the tubules: 45 per cent of the cells were white, under conditions where as yet no germinal variegation has been found. Cytological study of the salivary glands from similar individuals gave 67 per cent of the cells deficient for the affected portion. Finally, in such flies, most of the imaginal tissue has undergone variegation for the white locus. There is apparently a close correlation between the extent of variegation in a given tissue and the stage in development at which that tissue is laid down. According to the embryological study of Dr. D. F. Poulson, the order in time of appearance is first germ cells, then the malpighian tubules, then the salivary glands and last the imaginal discs. The later in development an organ is laid down, the more extensive the variegation. This raises the question of the effect on variegation of changing the balance of the heterochromatic regions. With the increase of the amount of heterochromatic regions relative to the euchromatic, the variegation is increasingly suppressed. Is it the stage of development at which variegation occurs or is it simply the frequency of variegation that is affected? From an analysis of the size of the mosaic patches, it would appear that

the chief effect is on the stage of development, presumably on the cell division, at which variegation occurs; instead of many small patches, whole organs are affected, almost as units, when the heterochromatic balance of the nucleus is changed. This conclusion is of particular importance in connection with Noujdin's discovery of a maternal effect of the heterochromatic regions on variegation. The data suggest the likelihood that the heterochromatic regions are concerned with the production of some substance, synthesized in the oogenesis, depleted during the cleavages of the early embryo, and whose synthesis anew begins at earlier embryonic stages when more heterochromatin is present. Schultz's cytological studies of the effects of heterochromatic regions on the salivary gland chromosomes give an indication of what this substance may be.

In the X-4 translocation referred to previously, the breakage point in chromosome 4 lies within the heterochromatic regions. Accordingly the neighboring euchromatic X region could be studied in the heterozygous translocation and compared with the same region in the normal X chromosome by its side. As a result of the translocation, two or possibly three bands (3E1, 3E3), normally quite faint, have become appreciably darker. This effect has been verified in two different stocks of the translocation as compared with three different normal X chromosome stocks. It appears not only when the chromosomes are stained with aceto-carmin, but is evident as well in preparations stained by the Feulgen method for nucleic acid. This means that in some way heterochromomeres are concerned with the amount of nucleic acid in other portions of the chromosome. According to the recent work of Caspersson, the bands of the salivary gland chromosomes consist of nucleoprotein, the portions between of protein alone. It follows that either the heterochromomeres are centers of the synthesis of nucleic acid, or that they change in some undefined way the capacity of the protein to combine with nucleic acid. It should be noted that such an effect of the heterochromatic regions was previously noted, although not yet tested by the Feulgen method, when the number of Y chromosomes is changed. The suggestion is tempting that the substance referred to above, influencing the extent of variegation, is the nucleic acid portion of the chromosomes.

It should be noted that this effect of heterochromomeres on neighboring euchromatin is a cytologically visible position effect. A possible mechanism for the genetic position effects, somewhat different from those previously suggested, is thereby indicated. We now have to deal not with the diffusion of gene products into the cytoplasm, but diffusion along the chromosome of substances produced at special places within them. Whether this actually is genetically applicable remains for further study. It is not inconsistent with the available data. Particularly, it can be shown that in the Bar case, the degree of departure from the normal phenotype is correlated with an increase in the distance apart between two genes outside the duplicated section.

Heterochromomeres are distinguished by their capacity for non-homologous association with each other. That this is really non-homologous is evidenced by the location of the genes bobbed in X, light in II and bent in



IV all in heterochromomeres, which have this property of non-homologous association. The discovery of Bauer that chromosome ends also have the property of attachment to each other raises the question of the relation between these non-homologous attractions. A test is provided by the study of the relation of ends of chromosomes to heterochromomeres brought near to them. In the variegated white translocation discussed previously, it was found that out of 146 nuclei examined, in twenty-three cases the tip of X was attached to the heterochromatic portion of the translocated fourth chromosome; in two cases the tips of X and 4 were attached; in three cases the tip of 4 and some other chromosome were attached; sixty-four cases had free ends; and forty-five could not be analyzed. This relation has been verified in three different stocks of normal X chromosome and in two different translocation stocks. It must be concluded therefore that the two types of non-homologous attraction are related if not identical.

Some information as to the nature of the changes in pigmentation of different mutant types may be obtained by observing the effects of supplying an excess of the pigment normally present in such cases. Where the pigment or its precursor is the limiting factor, newly added pigment will be retained. The recent discovery of Beadle that the malpighian tubules of larvæ of the different eye-color types are also different from the normal makes these organs useful for such a purpose. The malpighian tubule pigment is related to the pigments of the eye in *Drosophila*. Morgan had earlier shown that the tubules of the adult absorb eye pigment selectively: hence even in the normal *Drosophila* they are not maximally pigmented. In collaboration with Dr. J. L. Monod, Schultz has experimented with the partially purified eye pigment. The comparative behavior of white, wild type and variegated white malpighian tubules and of the tubules of other mutant types, following injections of the eye pigment, have been studied. In those mutants where the yellow vacuoles, present in the normal malpighian tubules, occur, the pigment is taken up by them. When these are not present, the pigment either is excreted immediately into the lumen of the tubule or very occasionally, when high concentrations of pigment have been injected, remains as red granules. Thus the difference between white and wild type, when excess pigment is added, as in the normal flies, is determined by the behavior of vacuoles which combine with the pigment. This is especially well shown in the variegated types: the cells with yellow vacuoles retain the pigment, those without do not. These vacuoles apparently belong to the class of lipochondria, studied by Reis. According to his account they are the cytoplasmic elements especially concerned with secretion, giving rise in the course of the process to the Golgi apparatus. Thus in different mutant types, the number and character of these vacuoles, which take up neutral red and release it, are varied. Evidently we have here the opportunity for a study of the relation between nuclear and cytoplasmic components, with reference to the changes caused by specific mutations.

In addition to the effects noted on the yellow vacuoles, it has been found that, in certain types, the nuclei of the malpighian tubules are vitally stained by the eye pigment. This is best shown in white malpighian tubules;

it is at a maximum three hours after injection. Thereafter the color is lost. The stain is taken both by chromosomes and nucleolus; its occurrence is dependent on the genetic constitution of the cell, as well as on the concentration of pigment injected and other environmental factors.

The giant *Drosophila*s, studied by Gabritchevsky and Bridges some years ago, may be considered as a problem in the control of pupation. The effect on the pupal stage is slight, if any; the cause of the giant character is an extension of the larval life, that is a delay of about four days in the onset of pupation. The recent work of Fraenkel on *Calliphora* has shown that in *Diptera*, as in other insects (Wigglesworth, Kopec, *et al.*) the onset of pupation is controlled by a hormone, released at a specific time. The question then arises whether in the giant *Drosophila*s, it is the time of release of the hormone or the sensitivity to a given concentration thereof that is changed. Schultz studied this by Fraenkel's method: constriction of the larva at definite stages prior to pupation, and determination of the pupation relative to the place of constriction. Constricted individuals in which pupation has occurred in both halves are those in which the hormone has already been released and distributed through the body. When release of the hormone has not yet occurred, pupation occurs only in the portion containing the hormone-producing organ. Three series of experiments were carried out, in which larvæ from a giant stock, of a known age, were constricted and allowed to pupate. It was found that the pupation hormone is released shortly before the time of pupation—2 to 3 hours, both in the giant and (unpublished experiments of C. W. Clancy) in the normal *Drosophila*. The hormone-producing organ is in the anterior end; although in a number of instances pupation in the posterior end only was found. These are, however, undoubtedly due to injury; partial pupation is not infrequent in *Drosophila* larvæ injured by injection. From these results it would appear that the delay in the onset of pupation of the giant occurs because the release of the hormone is later in giant than in wild type; these experiments give no information, however, concerning changes in sensitivity to, or amount of, the hormone produced.

## CHEMISTRY

The following reports have been submitted from investigators who have been appointed Research Associates of the Institution for studies in heavy hydrogen with funds made available for this purpose by the Carnegie Corporation of New York.

**Leighton, P. A.**, Stanford University, California. *Studies on the use of heavy hydrogen for determination of mechanism of photochemical reactions.*

With the aid of a grant from the Carnegie Corporation of New York, and under the sponsorship of the Carnegie Institution of Washington, a program of research has been inaugurated which has as its chief objectives the study of the photochemistry of deuterium and deuterium compounds and the use of deuterium as an indicator of mechanism in photochemical reactions. With the collaboration of Stanford University, Dr. Paul C. Cross has been giving his entire time to this project.

The photochemical exchange reaction between hydrogen chloride and deuterium, and the thermal equilibrium between hydrogen chloride, deuterium, deuterium chloride, and hydrogen have been studied.<sup>1</sup> A gas density balance was used for analysis of the hydrogen-deuterium mixtures obtained. The thermal equilibrium was measured over the range 390° to 944° K and found to agree, within limits of error of  $\pm 0.3$  per cent in the hydrogen-deuterium analyses, with the theoretical values as calculated from thermodynamic data. The photochemical exchange reaction (produced by the 2000 to 2200 Å lines of the zinc spark, absorbed by hydrogen chloride) approached on continued exposure a photostationary state in which the hydrogen-deuterium ratio was slightly larger than the calculated value for the thermal equilibrium at the same temperature. Starting with pure hydrogen chloride, the initial overall rate of the exchange reaction was found to be given experimentally by

$$\frac{d(H)}{dt} (av) = k I_0^{\%} (D_2)$$

where  $\frac{d(H)}{dt}$  is the rate of exchange of hydrogen atoms,  $I_0$  the incident light intensity, and  $(D_2)$  the deuterium concentration. The local reaction rate, at any given point in the reaction cell, is given by

$$\frac{d(H)}{dt} = k' I_{abs}^{1/2} (HCl)^{1/2} (D_2)$$

where  $k' = \frac{k\alpha^{\%}}{2}$ ,  $\alpha$  being the average molecular absorption coefficient of

hydrogen chloride for the zinc spark lines used. The overall quantum yield, depending on light intensity and deuterium pressure, varied from 3 to

<sup>1</sup> P. C. Cross and P. A. Leighton, Jour. Chem. Phys., vol. 4, 28, 1936.

30. From the information available, the following definite conclusions may be drawn:

1. The exchange is propagated by atomic chains, initiated by the photo-dissociation of hydrogen chloride, and stopped by recombination of atoms.

2. The reaction  $\text{H} + \text{D}_2 \rightarrow \text{HD} + \text{D}$  is rate determining.

3. Both this reaction and the atomic recombinations are three body processes involving an HCl molecule as the effective third body.

The application of deuterium to the photochemistry of ammonia and hydrazine is now under investigation. Mixtures of gaseous deuterioammonia and gaseous hydrazine have been found to exchange hydrogen atoms spontaneously at room temperatures. Even between gaseous ammonia and solid hydrazine at  $-80^\circ \text{C}$ . a perceptible exchange occurs. As a result of this thermal exchange, the attractive prospect of following the photochemistry of deuterioammonia-hydrazine mixtures has been abandoned. Meantime, the quantum yield of photodecomposition of pure deuterioammonia has been found to be 0.12 as compared with 0.16 for ordinary ammonia at atmospheric pressure, and work is in progress on the rates of photochemical exchange of atoms between deuterioammonia and hydrogen, ammonia and deuterium, and hydrazine and deuterium.

The third problem to receive our attention has been the possible use of deuterium as an indicator of mechanism in the photochemistry of the aldehydes. Several attempts have been made to synthesize the compound  $\text{CH}_3\text{CDO}$ , with a view to a study of its photolysis, but a satisfactory product has not been obtained and the work is being continued. An investigation of the extent of the exchange reaction between acetaldehyde and deuterium-oxide is in progress.

**Urey, Harold C.**, Columbia University, New York, N. Y. *Studies on separation of heavy hydrogen isotopes.*

Two research projects have been carried on during the year—the construction of a mass spectrometer for the analysis of isotopes and the construction of a fractionation column for use in the separation of isotopes.

The mass spectrometer was constructed with the help of Dr. W. W. Lozier. This apparatus followed the general lines of the mass spectrometers constructed by Dr. Walker Bleakney, designed primarily for determining the relative abundance of isotopes in gaseous substances. This apparatus was constructed during the first part of the year and was in operation during February and March. At this time analyses on the carbon isotopes were completed in connection with other work going on in our laboratories. At the end of this time the winding of the magnet short-circuited and since then work has gone on in repairing the mass spectrometer, but it will still be some time before it is back in operation. Not much productive work was secured with this instrument during the year, but with the apparatus still available and work being done upon it, it should be useful during the coming year.

The fractionation column is one of new design, designed primarily for separating substances with close boiling points or very nearly identical

chemical properties. This column has been constructed and has been in operation during the past months on exploratory projects to see which methods could be best used for the separation of the isotopes of carbon, oxygen, nitrogen, and hydrogen. The results on these isotopes can be summarized as follows:

(1) *The oxygen isotopes*—In this case we have attempted to separate the oxygen isotopes by the distillation of water and have secured up to the present time an increase in these isotopes by a factor of about 4.5. The apparatus transfers approximately one gram of  $O^{18}$  water from natural water to the higher concentrated water per 24 hours.

(2) *The carbon isotopes*—In working on the carbon isotopes we have used the exchange reaction between bicarbonate ion and carbon dioxide gas. Potassium bicarbonate solutions together with an extract of the enzyme, carbonic anhydrase, is pumped at a constant rate into the top of the column. At the bottom of the column the bicarbonate is converted to carbon dioxide by the addition of sulphuric acid and the carbon dioxide passes to the top of the column and escapes. With this process there is a concentration of  $C^{13}$  at the bottom of the column. Only two runs have been made to date. In the first the  $C^{13}$  concentration was increased from 1.06 to 1.36 per cent and in the second run, which was shorter than the first, from 1.06 to 1.21 per cent. These increases in concentration are small, but the quantities which can be produced are large as compared with other methods which have been reported to date. Approximately 0.75 of a gram of  $C^{13}$  is transferred from natural carbon to higher concentrations per 24 hours.

(3) *The distillation of methyl alcohol*—In the case of the distillation of methyl alcohol, the oxygen concentration has been increased by a factor of 2 in the course of four days, thus showing that there is a difference in the vapor pressures of the  $O^{16}$  and  $O^{18}$  methyl alcohols, though it is apparently too small to be of interest as a separation method as compared with the distillation of water. The carbon and hydrogen have not been analyzed at the present time.

(4) *The concentration of the hydrogen isotope was increased by the distillation of water by a factor of about 55 and the column was still not at its steady state*—There is every reason to believe that the concentration of the hydrogen can be increased considerably further though the speed of transfer is probably too small to be of interest in competition with the electrolytic method for the separation of hydrogen isotopes.

(5) *The separation of the nitrogen isotopes*—Other experiments in our laboratories have shown that there is a concentration of  $N^{15}$  in ammonium ion which is in equilibrium with ammonia gas. Though no experiments have been done with the fractionation column, it should be possible to use it in much the same way as is done in the case of the carbon isotopes described above.

In the problem of the separation of isotopes two things must be considered: in the first place, the enrichment of a light isotope or its increased concentration which can be secured, and in the second place the amount which can be produced per unit of time. In the experiments which we have done the enrichments secured are rather small as compared with those

which have been secured by Hertz, using his diffusion method. The quantities which have been transferred, however, are much larger than those secured by Hertz. In any of these fractionation processes the amount which can be transferred is roughly proportional to the concentration of the isotope which is being concentrated. Reducing his results on neon to what could be reasonably expected in the case of oxygen and carbon, we find that our method is approximately one thousand times as fast as his from the standpoint of the quantity transferred. It would be desirable to increase these quantities still further and it appears that distillation methods and the method of exchange reactions can possibly be adapted for still larger production of isotopes.

The apparatus is in active use and further results are expected during the next year.

**Rabi, I. I.**, Columbia University, New York, N. Y. *Studies on magnetic moments of heavy hydrogen nucleus in cooperation with investigations of Dr. Urey.*

These investigations have been concerned with measuring the spin and the magnetic moment, particularly the latter, of the nuclei of hydrogen and deuterium. Since these two nuclei are the two most elementary nuclear systems in the whole table of elements, it is of particular importance to have an accurate knowledge of these fundamental quantities. Furthermore, an accurate knowledge of the magnetic moment of the proton and the deuteron yields immediately a good first estimate of the magnetic moment of the neutron which is otherwise inaccessible to direct measurement at the present time. We have devised entirely new methods designed to achieve the best possible precision in these measurements. The results of our experiments have been communicated in five papers read at various meetings of the American Physical Society during the course of the last year. A complete article has been submitted to the Physical Review and will appear in the September 1st issue of this journal.

The results of our investigations are briefly as follows: We have found for the magnetic moment of the proton 2.85 nuclear units and 0.85 for the deuteron, which gives a value of  $-2$  for the neutron. We have also succeeded in measuring the sign of the magnetic moment of the proton and deuteron, that is, we can now tell whether the nuclear magnet points with the spin or in the opposite direction, a question hitherto undecided. The result is that the magnetic moment of both the proton and the deuteron point in the direction of the spin. The precision of our measurements of the magnitude of the proton and deuteron magnetic moments we consider to be of the order of 5 per cent.

## GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Cytogenetic and taxonomic investigations in the Crepidinæ*. (For previous reports see Year Books Nos. 25-34.)

In the last report reference was made to a plan for expansion of the investigations on *Crepis* to include several other genera, especially *Prenanthes* and *Lactuca*. The general procedure is similar to that which has been followed in the *Crepis* investigations. First, a preliminary taxonomic survey of the genera has been made. Second, as many species as possible are being cultivated at Berkeley. These will be studied cytologically with particular reference to the chromosomes, and experiments on hybridization of some of the species in each genus are being conducted. Third, the evidence from comparative morphology, cytogenetics and geographic distribution will be used in an effort to work out the systematic classification of the species involved on a more truly natural basis than has been possible in the past.

One of the most pressing questions encountered in such an undertaking is the determination of generic limits. For example, it has become increasingly clear that certain species which have long been classified as *Crepis* are not as closely related to the main body of *Crepis* species as they are to certain other genera. In some instances the proper disposition of such species, if they are to be excluded from *Crepis*, is a difficult problem, the solution of which involves the critical weighing of all the available evidence. As a result of the general survey of *Prenanthes*, *Lactuca* and certain smaller, closely related genera, the generic classification of several small, anomalous groups is being worked out.

*The genus Youngia*—A monograph of one such group of twenty-six species has just been completed by Babcock and Stebbins. Presumably it will be published in advance of the *Crepis* monograph. Nineteen of the twenty-six species have previously been classified in *Crepis*; one was originally published as *Lactuca* sect. *Ixeris*; and the other six are new species. It happens, however, that one of the nineteen species which have long been classified as *Crepis* (*Prenanthes japonica* L.) was described by Cassini in 1831 as the type species of the genus *Youngia*, and this becomes the name of the genus as it is the earliest generic name ever given to any member of this group, other than *Crepis*, *Prenanthes* or *Lactuca*. The evidence supporting the recognition of *Youngia* as a genus and the relations of *Youngia* to its nearest allies are fully discussed in this treatise. Monographic papers on several other small anomalous groups of species which are related to *Crepis* are in preparation. As the definite disposition of all these dubious borderline groups approaches completion, the final rounding up of the *Crepis* monograph also assumes a more definite prospect.

*The American species of Crepis*—Another very troublesome group of species, all of which are true *Crepis*, consists of the members of this genus which are indigenous in North America, excluding two members of an Old World group, *C. nana* Richards. and *C. elegans* Hook., both of which have 14 chromosomes. All the other American species of *Crepis* have 22 chromosomes or some other multiple of 11, a number not found in any other

species in this genus. It was suggested in 1930 by Hollingshead and Babcock (cf. Year Book No. 29, p. 40) that these American species, with 11 as the base number of chromosomes, may have originated through hybridization between 7-paired and 4-paired species followed by amphidiploidy. Although no more plausible hypothesis has been advanced, as yet no convincing evidence in support of this hypothesis has been found.

Continued study of these species, however, has shown that the group as a whole is very complex. Not only has interspecific hybridization occurred between several of the 22-chromosome species, but apparently this has been followed again by amphidiploidy, thus producing the highest known chromosome number in the genus, 88. Furthermore, certain hybrid forms with odd numbers, 33 and 55, are capable of producing seed through apomixis. Autotetraploid forms with 44 chromosomes also occur. Thus the American species of *Crepis* now present a very complex problem for the taxonomist. For the purpose of throwing further light on this problem, Dr. Stebbins has made a statistical study of comparative sizes of pollen grains and stomata in the various species. By using as the basis for this study those forms in which the chromosomes have actually been counted, it is possible to classify a large number of herbarium specimens according to their pollen and stomatal measurements into chromosome number classes. Such material can then be used in a study of geographic distribution in such a way as to throw considerable light on the general problem.

This investigation has been followed by a field trip in northern California during which Babcock and Stebbins made 114 collections of *Crepis*, representing six or more species and many different forms. Among these forms there are five that appear from their morphological features to be diploids (22 chromosomes). Cytological preparations of these and many other forms were obtained; emasculation experiments were performed for the purpose of checking on the occurrence of apomixis; and a census was made of the morphologically diverse races occurring at several different localities. The data thus obtained will be of great value in determining species limits and interspecific relations. A paper is in preparation which will present the results of these studies as applied to taxonomic classification.

*Prenanthes and Lactuca*—Dr. Stebbins has completed a preliminary survey of *Prenanthes* which includes about 40 species. Working descriptions have been prepared for the Old World species which comprise about half the genus. Cultures of several species of this genus are being studied cytologically by Dr. Jenkins. But many oriental species are very difficult to obtain and extremely difficult to culture when seeds are available. Furthermore, it has been impossible to make field studies on *Prenanthes*. The work under way is expected to lead to the preparation of a taxonomic revision of this genus. A preliminary survey of *Lactuca* shows that this large genus presents too many difficult problems to warrant an attempt to complete a monograph of the genus within a three-year period. Accordingly, as many species as possible are being grown in order to determine chromosome numbers. It may be possible to combine the data on chromosomes with the best available treatises on taxonomy in the preparation of a preliminary taxonomic revision of this genus.



During the past year the writer has been assisted in the *Crepidine* investigations by Dr. G. L. Stebbins jr., taxonomist and cytogeneticist; Dr. J. A. Jenkins, cytologist and geneticist; Mr. E. Jund, technician; and Miss Anna Hamilton and Mrs. Katharine Jenkins, artists.

**Davenport, Charles B.**, Cold Spring Harbor, New York. *Investigation on child development*. (For previous report see Year Book No. 34.)

During the year under review I have seen through the press the two volumes on Child Development and Statistical Methods, respectively, upon which I worked during the year. I have continued the cooperative studies on child development at the Normal Child Development Clinic, Columbia University, and at Letchworth Village.

Since children show very striking changes in bodily proportions, which are obviously recapitulatory, it was natural to look for similar changes in other mammals. With the cooperation of the American Museum of Natural History I measured the bones of young Primates and some other mammals. By a comparison of the proportions of the appendicular bones of young and adult of various species of mammals, conclusions could be drawn that probably have a phylogenetic significance. Thus, in the gorilla the humerus in relation to net arm (excluding hand) is less in young than adult; while radius length  $\div$  humerus length is greater in the young. The hypothesis would seem to be entertainable that the ancestors of the gorilla had a relatively shorter humerus than the adults have. Again in the chimpanzee, the tibia (of the lower leg) length  $\div$  femur length is shorter in the young than the adult; while radius  $\div$  tibia is greater in the young than in the adult. Hence the hypothesis that the ancestors of the chimpanzee had relatively shorter lower leg than the modern type. Applying this method to the walrus, it looks probable that its ancestors had longer hindlimbs, relatively shorter humerus and femur and longer tibia. A suggestion is made that museums would do well to collect more fetal and youthful material.

An analysis has been made, with the help of Mr. William Drager, of the growth curve of infants. For both body length and weight the growth curve is fitted, from birth up to 18 to 22 months, by the exponential equation  $Y = 10^{(a+bx+cx^2)}$ . Of the three terms of the exponent,  $a$  represents the size at birth;  $bx$  the acceleration factor and  $cx^2$  the retardation factor which makes itself felt with increasing vigor in the second half of the second year. Deviations from the smoothed curve are met with, especially at about 18 months, possibly due to walking, tooth cutting and other new activities. This phenomenon will be further studied.

Preliminary studies have been made on changes in facial features between 6 and 18 years. During this time the nose height tends, in the plurality of cases, to occupy a progressively larger part of the face. In a few cases it diminishes owing to the increasing size of the chin. Again, the proportion that the distance from ear opening to back of head is of head length diminishes from 6 to 10 years and then increases from 10 to 16 years. The early decrease is due to the post-natal development of the head; the later increase is due to post-auricular development of the cerebrum in which the adult has so markedly advanced over the anthropoid apes.

## METEOROLOGY

**Bjerknes, V.**, Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-34.)

Dr. Bjerknes reports personally as follows: In order to state a certain important progress made during the current year, I must go back to the time in the nineties of the last century when I began to occupy myself with the sciences of meteorology and hydrography.

The text-books of hydrodynamics of that time gave, as the most general results concerning fluid motion, the theorem of *Helmholtz* of the *conservation of vortex motion* and the equivalent one of *Kelvin* of the *conservation of circulation*. As the fluid was supposed to have idealized properties (to be either homogeneous and incompressible, or if compressible its density should be a function merely of pressure) these conservation theorems were in no actual contradiction with the empirical facts that the motion of real fluid media as atmosphere and hydrosphere consists in an eternal formation and annihilation of circulation and vortex motion. For the density in these media depends upon at least one more variable, *temperature*. But, as a matter of fact, these conservation theorems acted as a barrier, preventing hydrodynamists from seriously occupying themselves with meteorology and hydrography.

A special problem—to arrive at a complete theory of the hydrodynamic actions at a distance discovered by my father—caused me to cross this barrier. Giving up the above-mentioned restrictions set upon the fluid properties, I arrived at *laws for the formation and annihilation of circulation and vortex motion*, which were immediate generalizations of the conservation laws. I arrived at two theorems (I) and (II), giving the laws from two different points of view, according as the motion was described: (I) by the vector velocity; (II) by the vector momentum (or impulse).

Theorem (II) was what I wanted for my immediate purpose. It allowed me to develop from a new point of view the theory of hydrodynamic actions at a distance. But soon afterward I discovered that theorem (I) gave the means of discussing the formation and annihilation of atmospheric and oceanic circulations and vortex motions, considered as motions of thermal origin—a cause of motion which did not enter into the scope of the old “classical” hydrodynamics. This was the origin of the work which has been so generously subsidized by the Carnegie Institution from the year 1906. And in this work the theorem (I) has constantly played a great part, while theorem (II) did not come into use.

But as our work proceeded, a certain type of motions proved to be of increasing importance, namely *wave motions*, the waves being, however, of a much more complicated type than those treated in classical hydrodynamics. And here we met with the difficulty that we had no easy and intuitive method of dealing with these motions, comparable to the convenient methods of dealing with circulations of thermal origin by use of theorem (I). We saw

no other way of proceeding than taking up heavy problems of integration (see annual reports for the last ten or fifteen years).

But now I have found, almost to my surprise, that theorem (II) gives an equally excellent method of dealing with wave-motions as does theorem (I) for dealing with the circulations of thermal origin. This does not make it superfluous to look for complete solutions of definite problems by exact integration. The two methods supplement each other. The integrations give the full mathematical exactness, while the use of the theorems (I) and (II) has an intuitive character. And these theorems have the great advantage that they can be applied directly to observed data, and they thus establish an invaluable link between the empirical and the theoretical ways of investigation.

This parallel use of the two theorems was the subject of an address "New Lines in Hydrodynamics," given before the International Congress of Mathematics which met in Oslo in July this year. The address will be printed in the Report of the Congress. Further publications on the subject are planned, giving applications not merely to the dynamics of atmosphere and sea, but also to the internal dynamics of the sun and the stars (compare my paper "Solar Hydrodynamics," Year Book No. 26).

These "New Lines" will also exert a considerable influence upon the form to be given to part III, "Dynamics," of our planned work. (See the two preceding annual reports.)

Professor Solberg's important work on the theory of the tides has been mentioned in the last two annual reports. His first paper, "Über die freien Schwingungen einer homogenen Flüssigkeitsschicht auf der rotierenden Erde," on the subject has now appeared in the *Astrophysica Norvegica* (Vol. I, No. 7, Oslo 1936). The paper has immediately made an impression upon authorities on the subject.

In a second paper, "Schwingungen und Wellenbewegungen in einer Atmosphäre mit nach oben abnehmender Temperatur" (*ibid.* Vol. II, No. 2, Oslo 1936), he has given the theory of short-periodical oscillations in an atmosphere with linear field of temperature. A special result is a new formula for the propagation of sound waves in the atmosphere. It is more general than that of Laplace, which is valid only for a homogeneous medium. He has applied his formula to the sound waves which propagated round the Earth after the great fall of meteorites in Siberia in 1908. A later paper will expand this investigation to long-periodic oscillations, in view of further improvements of the cyclone theory.

A third paper, "Le mouvement d'inertie de l'atmosphère stable et son rôle dans la théorie des cyclones," will soon appear. It gives a new stability-criterion for a rotating fluid mass, more general than that given by Lord Rayleigh, which is valid for homogeneous liquids only. It will be of importance for the dynamics not only of our atmosphere, but also for that of the interior of the sun and the stars.

The successive improvement of the theory of cyclones, especially of their formation, is as a matter of course one of our principal aims. The main lines of the theory were given in a synthetic-elementary form in V. Bjerknes's paper "Circular Vortex" (see Year Books Nos. 20 and 22), and from that

time the corresponding mathematical theory has been subject to incessant work, especially by Professor Solberg (see previous annual reports).

To bring the mathematical results hitherto gained in as elementary physical form as possible, and to compare the results with our empirical knowledge, is the object of the following paper by J. Bjerknes and C. L. Godske, "On the Theory of Cyclone Formation at Extra-Tropical Fronts" (*Astrophysica Norvegica*, Vol. I, No. 6, Oslo 1936). J. Bjerknes sums up what is known empirically at the present date on the formation of the cyclones and of the approximate values of the quantities characterizing the front and the cyclone; while Godske discusses the different dynamical effects upon which the phenomena depend. The compressibility of the air is seen to be of only secondary importance. The primarily given effects are that of gravity and that of inertia (due to the rotation of the earth). But they give, neither separately nor combined, the required instability for the cyclone formation. The deciding unstabilizing factor is therefor the dynamical instability due to the sliding motion of the superimposed strata at the front. It is shown, by elementary considerations that at every front under the simultaneous action of the instability of inertia and instability of the sliding motion, unstable waves of very great length—order of magnitude 1000 km.—will arise, thus just of the length of the cyclonic waves observed on the weather maps.

J. Bjerknes has continued his empirical investigation of cyclones by serial ascents of registering instruments organized by cooperating aerological observatories. "Case 3" was reported in the last annual report, and "Case 4," February 15-17, 1936, which was also mentioned in the previous report, is still subject to finishing work. It has given the opportunity of drawing synoptic maps in the high levels, resulting in information of the perturbations in the "tropopause" (the boundary surface between troposphere and stratosphere) and the coupling of these perturbations with those below. "Case 5," October 17-19 1935, has not yet been taken up to examination as balloons are still found from time to time.

It may be mentioned as proof of the confidence which our work has gained, that Dr. Pettersen has spent most of the last year in the United States, having been invited to give instruction in the "Norwegian methods" of the Analysis of Weather Charts and Weather Forecasting; and that Prof. J. Bjerknes has passed five months with a similar mission in the Meteorological Office, Air Ministry, London, the special aim being to prepare meteorologically the future transatlantic aerial traffic.

## NUTRITION

**Vickery, H. B.**, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-34.)

The critical study of the dietary needs of the rapidly growing rats of our colony has been continued, with added emphasis on the inorganic salt requirement. As has been stated in earlier reports, we have arbitrarily selected the period of active growth from 60 to 200 grams body weight for comparisons, and much of our effort in the past has been directed toward the establishment of standards for the criteria we have employed. Last year we showed that within any group of ten animals that received the same ration, rapid growth led to the production of relatively low bone ash for that group. Data secured during recent months have given added support to that observation and have also indicated that we may expect our animals to make the gain from 60 to 200 grams in 24 to 28 days, or at the rate of 5 to 6 grams gain per day. A study of many groups of animals, subjected to a variety of dietary procedures, indicates that, with this rate of gain, the proportion of ash in the extracted femurs of a 200-gram male rat will be between 58 and 60 per cent. In the groups studied, the calcium intake has varied between 36 and 73 mg. per day, and the Ca:P ratio between 1:2.0 and 1:0.45. Even with the calcium intake at the highest level studied, the bone ash seldom exceeded 60 per cent, provided the high rate of growth mentioned was maintained. Some of these data are summarized in table A.

TABLE A

Gain per day	Calcium in- take per day	Ca:P ratio	Bone ash
<i>grams</i>	<i>mg.</i>		<i>per cent</i>
5.4	36	1:2	58.7
5.2	43	1:0.8	59.7
5.0	44	1:0.6	60.1
5.2	45	1:0.9	58.5
5.2	48	1:1	60.8
5.6	57	1:0.5	60.2
5.4	60	1:1	59.9
5.8	62	1:1	59.5
5.2	62	1:0.5	59.3
6.1	73	1:0.45	59.0

These observations have been made in the course of the study of our new salt mixture, which has been continued during the past year. To date we have checked this preparation in comparison with the Osborne-Mendel salt mixture with the use of low protein, high protein, low fat and high fat types of diet, and have obtained closely similar results as judged by rate of growth and percentage of ash in the fat-free femur. Further comparisons are needed before we can be sure to what extent the new preparation can replace the Osborne-Mendel salt mixture.

We have continued our investigation of the effect of repeated pregnancies and lactations on the storage of inorganic matter in the bones. Female rats have been bred according to our regular routine, which permits a rest of three weeks between weaning a litter and subsequent remating. As controls we have used virgin litter mates which were subjected to the same dietary treatment as that given the mated animals. Both the mated animals and the controls were sacrificed at the same time—in one series after the mated animal had weaned one litter of 8 young, and in the other series after three litters of 8 young each had been weaned. Our data show that there is a definite decrease in the percentage of ash in the femurs as a result either of one or of three reproductive cycles. The decrease, however, is not sufficiently marked to constitute a real depletion, and is no greater at the end of the third lactation than after the first. It would seem, therefore, that under the conditions of breeding employed in our colony at the present time, there is no excessive drain on the skeleton of the mothers.

It has been demonstrated in this laboratory by Professors Arthur H. Smith and William E. Anderson of the Department of Physiological Chemistry of Yale University that, from the standpoint of number of young produced and weight of young at weaning, the interval between weaning and subsequent remating may be safely reduced to one week. We are studying the effect of this more rapid succession of pregnancies and lactations on the store of inorganic material in the skeleton of the mothers. This work has not progressed far enough to be summarized at the present time.

Professors Smith and Anderson have concluded the investigation of the reproduction of the albino rat on a presumably complete diet. In previous reports attention was called to the probability that, even under favorable conditions of nutrition, the reproductive performance of this laboratory animal might be expected to show cycles of variation about a fairly high mean. This is again borne out by the observations of the past year. In the seventh generation, there was a slight regression in fertility in two out of three groups; on the other hand, there was a slight improvement in performance based on percentage of weanings; and the favorable trend in body weights noted in the sixth generation was maintained in animals of the seventh generation. The experimental group subject to a rest of three weeks between matings was discontinued at the end of the sixth generation. The data bearing on the seventh generation were obtained, therefore, on one less experimental group than heretofore. An extended report based on the available data for all seven generations is being prepared.

Last year, we reported that we were attempting to repeat with a modern type of diet the classic experiment in which Osborne and Mendel demonstrated the supplementary action of tryptophane and lysine in a ration that contained zein as the only protein. As is well known, this observation was made at a time when "protein-free milk" was a constituent of all of our so-called purified diets. Professor Mendel felt that this experiment (as well as many others that were conducted at that time) should be repeated and extended with the object of confirming the original observation with the highly purified diets now available. Accordingly, we have repeated the work, both with the old type diet using protein-free milk and with a modern

one, and have been able to duplicate the earlier observations in all essential features. We have obtained a response similar to that reported in 1914—namely maintenance with the addition of tryptophane, and growth with both tryptophane and lysine as supplements to the zein. The growth in 1914 was similar to that obtained with other rations—or approximately normal growth for the colony. In our recent experiments, however, we have never observed a rate of growth comparable to that characteristic of the colony today, even when protein-free milk was supplied in the ration. This suggests that there may still be some as yet undetected deficiency in these diets.

The experimental work designed to determine the optimal calcium and phosphorus ratio in the diet, carried out some years ago in collaboration with Dr. E. A. Park, has recently been summarized by Dr. Park, with such assistance as we could render. A careful study of the data now indicates that some of the earlier observations should be checked and extended before publication. This work is in progress.

The work on the effect of daily injections of thymus extract, undertaken in collaboration with Dr. Leonard G. Rowntree of the Philadelphia Institute for Medical Research, has been continued. We have not been able to conclude an experiment which we consider satisfactory. This has been due in large measure to the great difficulty in the preservation of potent extracts. At the present time Dr. Rowntree is making every effort to see that we are furnished material of unquestioned potency and we hope to be able to make a definite report in the near future.

An important part of the chemical work of the laboratory this year has consisted in the analysis of a series of samples of tobacco leaves that had been subjected to culture on water, on glucose, or on ammonium sulfate solution in the dark, and of similar samples cultured in light. The preliminary investigation on water culture carried out three years ago showed that much could be learned in this way of the nature of the chemical reactions that occur within leaf cells, and the work has now been materially extended. The technique employed enables us to express the reactions in terms of actual quantities of metabolizing substance per unit of fresh leaf tissue—a method of expression which yields more vivid and easily appreciated results than can otherwise be obtained. The data at hand refer to the changes in organic solids and in water content, to the changes in the several forms of nitrogen for which we have trustworthy analytical methods, and also to the changes in the chief organic acids and in the carbohydrates. Although it is too early at the present writing to make detailed statements regarding the observations, it has become clear that this type of experimentation yields information that is extremely helpful in understanding the reactions that occur in leaf tissue. The comparison of the effect of light upon the various reacting constituents is particularly striking. For example, oxalic acid remained essentially constant in amount both in light and in the dark; citric acid increased markedly in the dark, but remained constant or diminished somewhat in light. Malic acid decreased very materially in the dark but remained substantially unchanged in light. The nitrate showed the phenomenon we have previously observed of increasing substantially in the dark in the early stages of culture and subsequently diminishing. In the light, on

the other hand, it diminished in a fairly regular manner on water, or on glucose, but fluctuated between rather wide limits on ammonia culture.

It is our purpose to attempt to obtain explanations in chemical terms of as many of the chemical phenomena as possible. We feel that we are already in a position to account in part for the changes in the amide content of the leaves. Certain of the changes in protein nitrogen, in amino nitrogen and in the carbohydrate factors can also be explained in a reasonable manner. But the behavior of the individual organic acids, of the nitrate, of the non-fermentable carbohydrate, and even of the free ammonia provide puzzling aspects which can be resolved only by continued investigation.

In the hope of obtaining further information on some of these problems, leaves have been cultured on water, the cultures being placed alternately in light and in the dark for one and for two day intervals in each situation. Controls under both conditions have also been conducted. The analytical work on this material is now in progress. These investigations have been carried on with the able cooperation of Dr. G. W. Pucher of the Experiment Station staff attached to our laboratory.

Work on the problem of amide metabolism in plants has been continued. The development of an improved method to determine glutamine was referred to last year, and this has now been published in the form of a collaborative paper with Professor Chibnall and Dr. Westall of Imperial College, London, England. A thorough study was made of the effect of drying upon the apparent glutamine content of tomato plant tissues. The preparation of samples of tissues in a form that can be preserved for subsequent analysis is a serious problem in plant biochemical work, and is especially difficult when attention is being paid to substances as unstable as glutamine. The most trustworthy analytical values for this substance are probably to be obtained by prompt analysis of the fresh tissue, but, as this is technically impossible when a large series of experiments is being conducted, the effect of drying the tissue under various conditions was examined. The drying equipment employed has provision for circulating the air rapidly over the tissue and the temperature is controlled by a thermostat sensitive within  $\pm 2^\circ$ . Comparisons were made between the glutamine content of tomato leaves as determined in water extracts of the fresh tissue after cytolysis with ether, and as determined in the tissue after being dried at 70, 80, or 90° C. Although the free ammonia was slightly increased by the drying operation and the glutamine amide nitrogen was slightly diminished, the ratio between the glutamine amide nitrogen of the dried and of the fresh samples was 98, 97, and 96 per cent in the three cases. Destruction of glutamine under the conditions employed was therefore negligible and it seems established that our customary technique of drying at 80° in this apparatus is permissible. It should be noted, however, that the time of drying is of importance—conditions must be adjusted, particularly with fleshy tissues, so as to reduce this to the minimum.

In our earlier work on the culture of tobacco leaves in water, we obtained evidence for the presence of a substance which was decomposed with the formation of ammonia during the preparation of a hot-water extract of the tissue; this was referred to at the time as "easily hydrolyzed amide nitro-



gen." Evidence accumulated since has made it probable that the substance involved is glutamine. To make this certain, we have isolated the amides of tobacco leaves in crystalline form. An extract from some 13 kilos of fresh leaves contained 1.38 grams of glutamine amide and 2.26 grams of asparagine amide nitrogen as determined indirectly. The regular procedure for the isolation of the amides was applied, and, by fractional crystallization, the equivalents of 0.588 gram of glutamine amide nitrogen and 1.67 grams of asparagine amide nitrogen were secured as analytically pure substances, yields of 43 and 74 per cent, respectively. When the nature of the operations necessary for this isolation are taken into consideration, these yields are highly satisfactory. This observation accounts for our former results, and makes it clear that glutamine plays an important part in the amide metabolism of the tobacco plant.

A study of the glutamine metabolism of the common beet has also been made. It was found that when normal plants growing in the field were treated with ammonium sulfate applied in dilute solution at the rate of one ton of nitrogen per acre, there was a prompt and striking response in the content of glutamine in the root tissue. The roots at the start contained 0.186 gram of glutamine amide nitrogen per kilo; three days after the treatment this had increased to 0.268 gram and a week later, after an additional 500 pounds of nitrogen per acre had been applied, to 0.289 gram. Meanwhile the asparagine amide nitrogen remained essentially constant, the increase from 0.027 to 0.058 and subsequent decrease to 0.026 gram per kilo being insignificant. The increase in soluble nitrogen of the tissue was almost quantitatively accounted for as an increase in glutamine. This implies that the nitrogen absorbed during the experimental period was assimilated almost entirely as glutamine.

A similar experiment in which beets grown in a greenhouse were treated daily with small amounts of ammonium sulfate showed an even more striking increase in the glutamine amide nitrogen of from 0.276 to 0.816 gram per kilo, again with but little change in the asparagine content. The final sample which had received nitrogen at the rate of 2550 pounds per acre was taken at the end of 18 days. The plants had been severely intoxicated by the ammonia, but the glutamine content of the roots had reached the phenomenal figure of 5.4 per cent of the dry weight of the tissue. These experiments clearly exemplify the important function of glutamine in this species as a detoxicating agent for ammonia of extraneous origin. Furthermore it has become clear that both nitrogen atoms of glutamine share in this function, and accordingly it may be inferred that the precursor of the glutamine is non-nitrogenous.

Much time has been devoted to the further development of a method to determine purine nitrogen in plant tissues. The application to samples of dried leaf tissue provided a number of unexpected difficulties, but these have now been for the most part surmounted. The method rests upon the observation of Graf and Maculla that purines are quantitatively precipitated by the addition of freshly prepared cuprous oxide to a sample of the extract buffered at approximately pH 5. The precipitate is decomposed by the

action of trichloroacetic acid, the purines are reprecipitated in the same manner and nitrogen is determined in the precipitate. In this way dangers of loss due to adsorption on inorganic precipitates are avoided. The method is capable of determining from 0.1 to 1 mg. of purine nitrogen with considerable precision, and can therefore be applied to 1 gram samples of tissue. Preliminary observations have already shown that the soluble purine undergoes an interesting series of changes during water culture of tobacco leaves. It is becoming fairly evident that the nucleoproteins of the tissue are rapidly attacked early in the culture period with the liberation of additional purine in soluble form. Subsequently on culture in the dark, the purines undergo oxidation and are greatly diminished in amount. It is hoped that the procedure will be of much service in our efforts to obtain an understanding of the metabolism of the nucleoproteins of leaf tissue.

During the year we have had the able cooperation of Dr. James Melville, a Commonwealth Fund Fellow, who has been a guest in our laboratory. Formerly a student of Professor Chibnall, he has been of great assistance in our plant investigations. He has devoted his time chiefly to a study of the dicarboxylic amino acids of proteins, a further understanding of the properties of these substances being essential to our investigations of the plant amides. He successfully synthesized the extremely rare substance oxyglutamic acid by the method of Harington, and showed that a quantitative method for its estimation could be developed from the behavior on oxidation with permanganate and bromine, a direct application of our method for the determination of malic acid. He has also laid the foundation for a new and improved method to determine glutamic acid in proteins. After the hydrolysate has been boiled at pH 3 for a sufficient length of time to convert the glutamic acid to pyrrolidone carboxylic acid, this latter substance can be readily and quantitatively removed by extraction with ethyl acetate in an apparatus of the Widmark type we developed some years ago in connection with our work on plant organic acids. The pyrrolidone ring is then open by hydrolysis with dilute hydrochloric acid, and the glutamic acid is isolated as the hydrochloride. Foreman's value of 21.8 per cent of glutamic acid in casein was confirmed by this method. This investigation will be continued.

Dr. H. E. Clark, who spent two years in our laboratory as a National Research Fellow, has now published his interesting results on the composition of the tomato plant when cultured on nitrate solutions or on ammonium salt solutions. The remarkable enrichment in glutamine which occurs in this plant when grown on ammonia culture was referred to last year as well as the striking increase in inorganic acids when the plants are grown on nitrates. Dr. Clark has pointed out that there is a close interrelationship between the quantities of organic acids and of inorganic basic constituents and also between these and the nitrogeous ion available to the plant. The entire metabolism is affected by the nature and concentration of this ion, and clear evidence was secured of the complexity of the effects produced.

The following have served as assistants in the work: Alfred J. Wakeman, Ph.D.; Charles S. Leavenworth, Ph.B.; Rebecca B. Hubbell, Ph.D.; Laurence S. Nolan, technician; Luva Francis, secretary.

**Sherman, H. C.**, Columbia University, New York, New York. *Relation of food to length of life.* (For previous reports see Year Books Nos. 32-34.)

This program has been made possible by reason of grants from the Carnegie Corporation of New York, and the plan of research outlined in the reports of the past three years has been continued.

(1) The experiments designed to ascertain more precisely which chemical factors are concerned, in the improvement of an already adequate diet which we had previously reported, are now well advanced toward completion. The experimental animals (rats) of this series are all over two years of age and may therefore be expected to complete their life cycles within another year. Of the animals of this series which have already died, the greater number have been submitted to careful post-mortem examination by Dr. Sproul or Dr. Wilens in the Department of Pathology, Columbia University. As wide a variety of major lesions at death has been found as would perhaps be expected in a like number of autopsies upon elderly people; and the moderate differences in diet here studied do not seem to have predominantly influenced the causes of death. At the time of writing, all of the animals included in this particular comparison have completed that portion of the life cycle which furnishes the chief objective criteria of health and vitality during early and middle age. As the problem of possible relationships between the effects of food upon early growth and adult vitality and the effects upon length of life has been included in our plan of research throughout, we are now collating and preparing for publication the data on growth, size, and success in the production and rearing of young by these animals whose natural lives will presumably all be completed by midsummer of 1937. As previously explained, these experiments were started at intervals distributed over a year in order that the seasonal influences should be properly equalized in the composite picture afforded by the average of the life histories when completed. As judged from the data now in hand, a more rapid growth is induced when our previously described Diet A is enriched in calcium or calcium and butterfat up to the level of Diet B, while similar enrichment with butterfat alone seemed to result in slower early growth but larger adult animals. Such enrichment of the diet with butterfat (vitamin A), calcium, or both, resulted in a longer period of adult vitality as measured by the length of time during which the females were able to produce young. Earlier maturity appears to have resulted from the enrichment of the diet with calcium but not from its enrichment with butterfat. Enrichment with protein to a small extent and to a larger extent with both calcium and vitamin G (lactoflavin), by addition of skim-milk powder in replacement of about one-fifth of the ground whole wheat of the original Diet A, increased the rate of growth and the success in production and rearing of young to a somewhat greater degree than did the corresponding enrichment with calcium either alone or with vitamin A (butterfat). In all these cases the enrichments were only of the order of the differences between our diets A and B; but while awaiting the completion of the life histories of these animals we are also experimenting with greater enrichments of the diet in its calcium, phosphorous, and protein contents and in its vitamin G (lactoflavin) value. Corresponding systematic and compre-

hensive studies of the effects of enriching the dietary in other vitamin values are greatly to be desired, and will be included in the further development of our investigation if circumstances permit.

(2) The possible further improvement of the better of the two adequate diets upon which we have previously reported has here been studied in strictly comparable experiments with our Diet B (Laboratory No. 13) and a modification thereof by supplementary feeding of definite allowances of meat (lean beef) and a fresh vegetable (string beans)—this modified diet being identified as Laboratory No. 138. The fresh meat and fresh vegetable were fed on alternate days, each three times a week, while both the animals which received these fresh foods and those which did not had always before them the favorably proportioned wheat-and-milk mixture which constitutes our Diet B. The effect of thus adding two kinds of fresh food, to the already good but monotonous dietary consisting of dried whole milk and ground whole wheat, was to increase the growth and average size, while the effects upon adult vitality can be judged only upon the completion of the breeding records probably four to five months hence and those upon length of life about a year later. Several of the animals which served as subjects in this series have been utilized also in Dr. Benedict's study of the energy metabolism in old age.

(3) The experiments with still more varied diets, such as are commonly consumed by American families, have been and are being continued. Having found, as reported last year, that a food supply of this type originally supposed to be adequate proved too low in calcium content for support of normal nutrition through successive generations, we are now engaged in a new series of experiments in which the basal diet is: Dried lean beef, 5 per cent; dried potato, 9 per cent; dried lettuce, 1 per cent; dried orange juice, 4 per cent; dried whole milk, 15 per cent; lard, 7 per cent; butterfat, 4 per cent; ground whole wheat, 50 per cent; and sugar, 5 per cent. Parallel with this, we are also feeding modifications of it—in some cases enriching it simply in calcium content; in other cases varying the quantitative proportions of the staple foods in the dietary. The planning of these new diets has profited by the findings of other work in this laboratory, and now that the approaching completion of the experiments described in sections (1) and (2) above is making available the needed laboratory space, we are rapidly increasing the numbers of these experiments with more varied diets designed to throw even more direct light upon the nutritional possibilities of human food supplies.

The continued counsel of Dr. F. G. Benedict, and the efficient collaboration of all who have cooperated in these investigations, whether as research assistants or volunteers, are gratefully acknowledged.

## PALÆONTOLOGY AND GEOLOGY

**Merriam, John C., and Associates.** *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-34.)

The researches conducted by John C. Merriam and associates in the past year have followed in the main the lines of investigation of the preceding year. They have included problems concerning the history of vertebrate life on the Pacific Coast; the sequence and correlation of geological formations in which these vertebrate remains have been found; studies on evolution of the whale group; researches on the occurrence, history, and environment of early man on the Pacific Coast and in the southwest; investigations relating to interpretation of the geological and palæontological sequence at the Grand Canyon; an attempt to advance somewhat our interpretation of the meaning of history as it involves geological, palæontological, and archæological sequences; and the effort to obtain a better understanding of human values represented in the appreciation of nature.

Researches on the history of vertebrate life on the Pacific Coast have been conducted mainly by Dr. Chester Stock with a number of associates concerned with special phases of this problem. Investigation of the geological sequence in which the extinct vertebrates of the west coast are found has been carried on by Dr. Chester Stock, Dr. John P. Buwalda, and others.

As in previous years, the extremely interesting investigations relating to evolution of the highly specialized whale group have been conducted by Dr. Remington Kellogg. An outstanding element in development of this program is represented by the completion and publication of a large monograph on the Archaeoceti, or ancient whales, by Dr. Kellogg. It is important to repeat in this connection a statement which has been made in earlier reports to the effect that, although the history of the whales is something far removed from the immediate acquaintance of most persons, this sequence presents one of the most important of all evolutionary series known to science, and is therefore of great importance as an illustration of the process of change in living forms.

Investigations bearing upon the problem of early man in the west have been carried out largely by Dr. Edgar B. Howard of the Philadelphia Academy of Sciences and the University of Pennsylvania, Dr. H. de Terra, Dr. Ernst Antevs, Dr. Paul MacClintock of Princeton University, Dr. Paul B. Sears of the University of Oklahoma, Mr. M. R. Harrington of the Southwest Museum, and Dr. Chester Stock of California Institute of Technology. These researches, as recorded in another portion of this report, have touched on many aspects of the early man problem, including studies of the geological succession of formations, climatic variation during the period in which these formations were being laid down, investigation of the associated animals and plants, and the search for artifacts and human remains in a wide variety of formations ranging from the broadly distributed deposits near Clovis, New Mexico, to research on caves at various points in the southwest. The contribution from these investigations includes some of the most important additions to our knowledge of early man in America.

In connection with researches on the problem of early man in Florida important cooperation has been given by Horace G. Richards in study of the later deposits along the shore line.

Studies at the Grand Canyon have extended investigations of earlier years, and are carried on for the purpose of filling some of the most important gaps in our knowledge of that great section. It is recognized that in a story as extended and as near to completeness as that of the Grand Canyon any element of information added to what is already known finds an extremely important place in the geological record of the world. Dr. Ian Campbell and Dr. John H. Maxson of California Institute of Technology have continued their studies on the Archean rocks, the oldest section of the Canyon, and are planning to carry out a program of more intensive investigation at the earliest possible time. These researches are among the most important being conducted in America on the beginnings of geological history. Dr. N. E. A. Hinds, of the University of California, has carried forward his researches on the Algonkian sequence of rocks, this being the next stage above the Archean, and has in the past year published an important paper under the title "Uncompahgran and Beltian Deposits in Western North America." The investigations of Dr. Hinds and his associates have made one of the most significant contributions to knowledge of this imperfectly known section of geological time. It is important to call attention to the fact that the rocks of this Algonkian stage are the oldest in which we find relatively little changed deposits giving us an accurate picture of conditions on the earth at the time the formations were laid down.

Study of the formations above the Algonkian has been carried out largely under the guidance of Mr. Edwin D. McKee, Chief Naturalist of the National Park Service, at Grand Canyon. Mr. McKee has made investigations widely over the Grand Canyon region, extending down to the area of the Boulder Dam. These observations have made it possible to work out correlations of the formations and give us a better picture of the geological sequence in the Grand Canyon region. Mr. McKee has occupied himself to some extent with study of the Devonian rocks representing the so-called "Age of Fishes" in which important contributions have been made. His principal researches have been on the Kaibab formation representing the latest stage of the Grand Canyon in the region of El Tovar. These researches by Mr. McKee give extremely important additions to knowledge relative to the nature of the rocks, the mode of their origin, and the life forms included in them.

In connection with work on some of the formations below the Kaibab in the principal sections of the Grand Canyon, Mr. McKee has attempted to secure data which would aid in explanation of the structure and origin of these rocks. Especially was it important to have information concerning deposits which were evidently of fresh-water or brackish-water origin in the Supai formation in the middle of the upper section of the Grand Canyon wall. In order to secure data on this point, Mr. McKee has made a careful study of the building of the delta of the Colorado River in the belief that the manner of formation of that great deposit in process

of accumulation today might throw light on the structure and origin of the Supai in ancient geological time. Mr. McKee's results may be noted by the following quotation from a preliminary report:

"In the delta of the Colorado River, in Mexico, where fluvatile, acolian and marine sediments merge and where an arid climate prevails, the writer sought the answer to some of the problems presented by the Permian sediments."

"In the portions of the Colorado River delta examined by the writer, two distinctive types of deposits were readily apparent. One of these was in the lower section where the sediments consist entirely of fine mud or silt and where, in addition to annual floodings by the river, periodic overflows by marine waters occur at times of high seasonal tide. The other distinctive type was found in the upper part of the delta where the deposits are largely of fine sand, with some mud, and where, until recently controlled, great floods of the river periodically ran rampage.

"Analogy is suggested between the Supai formation as found in the Bright Angel area of the Grand Canyon and the upper portion of the Colorado delta. In both, the sediments consist of alternating layers of sand and mud and although the proportions are quite different, this is simply a matter of degree which presumably varies with the proximity to the head of the delta. In both instances the mud is flat-bedded; the sand largely, if not entirely, cross-laminated. The really significant similarity, however, is found in the analysis of the cross-lamination. Both of the types described from the delta area have counterparts in the Supai formation.

"The suggestion given by the comparison between the Supai formation and the present Colorado River delta is that the section of the Supai found in the Bright Angel quadrangle was built up on the middle portions of a large delta where sediments were brought from a great distance over flat terrain. It further appears evident that mud was deposited by the normal settling processes of flood plain deposition and sand was introduced during times of flood with accompanying current action as found in the upper portions of the present Colorado River delta."

Studies of the meaning of history in its various aspects have been carried out both with reference to practical aspects of this question as represented in geological, palæontological, archæological, and more recent historical sequences and through an examination of the philosophical significance of the whole field of history as it bears upon the development of man and of civilization. Recognizing that the longer reaches of time sequences as they relate to geology, palæontology, and archæology invariably give us pictures of change in phases of our natural environment and of man in that environment, effort has been made to formulate views as to the meaning of history applied to present and future stages in civilization. It has been assumed that the story of man would not follow precisely the lines taken by the trilobite or the dinosaur. At the same time it has seemed difficult to eliminate from the possibilities of human development some aspects of advance or growth or improvement which have characterized general biological sequences representing other forms in other ages. Appreciating the enormous difficulty of drawing any conclusions relating to man which can be

formulated with definiteness, and recognizing also the difficulty of anything like accurate prediction, it is nevertheless considered important to learn in how far the lessons of history may be useful in charting the course of mankind through future ages.

The relation of man to nature has from time to time been an important factor in scientific and philosophical studies, but has perhaps been looked upon as relatively less significant in recent periods, due to the fact that the works of man as a creative agent have seemed to overshadow other aspects of our relations and our development. It is nevertheless essential that man be viewed in his environment, and as in considerable measure coming out of it. It is important that we determine as nearly as we can both the influence of man upon nature and the influence of nature upon man. It is desirable that to some extent we take the longer view regarding the place of man in relation to nature through the ages.

Attention has also been given to the idea that the influence of nature upon man is a factor which offsets in some measure the results of clashing interests in human affairs. There is appreciation of the fact that among the various kinds of influences which affect mankind over the world one element, which is common to practically all peoples of the world, is that represented by the touch with nature.

#### *Researches of Chester Stock*

As in previous years, research in vertebrate palæontology conducted at the California Institute of Technology under grants from the Carnegie Institution of Washington relates to the history of Tertiary and Quaternary life of western North America. In Publication No. 473 of the Institution have appeared the following papers:

Schultz, J. R. *Plesippus francescana* (Frick) from the late Pliocene, Coso Mountains, California, with a review of the genus *Plesippus*.

Wilson, R. W. A Pliocene Rodent Fauna from Smiths Valley, Nevada.

Stock, C. A *Plomastodon* skull from the Thousand Creek beds, north-western Nevada.

In addition to these published papers there have now been completed two reports by Dr. Wilson. One relates to new middle Pliocene rodent faunas from Oregon and California in which are described important assemblages of rodents and rabbits from the Kern River beds of California and from Rome, southeastern Oregon. The second report by Dr. Wilson is a comprehensive review of all known Pliocene rodent faunas of western North America and marks an important advance in our knowledge of the history of this group of mammals during Pliocene time. Mr. John R. Schultz is completing an investigation of a late Cenozoic mammal fauna from the Coso Mountains, California. The papers by Wilson and Schultz are to be submitted to the Institution for publication.

#### QUATERNARY STUDIES

Results of a study of the geology and vertebrate palæontology of the late Quaternary near Clovis, New Mexico, with special reference to the occurrence of flints and extinct animals in pluvial deposits in this region have been published (C. Stock and F. D. Bode, Proc. Acad. Nat. Sci. Phila., vol. 88, pp. 219-241, 6 pls., 1936).



A statement regarding the succession of mammalian forms within the period in which human remains are known to occur in America, presented in a symposium on Early Man in America with special reference to the Southwest before the American Society of Naturalists, has been published (C. Stock, Amer. Nat., vol. 70, pp. 324-330, 1936).

At the invitation of the University of New Mexico and with the assistance of Professor Donald D. Brand, Frank C. Hibben and Wesley Bliss of that institution, an occurrence of Quaternary animal remains and flint objects in a cave in the Sandia Mountains, New Mexico, has been examined. Preliminary investigation is under way of the material thus far obtained. Further excavations need to be conducted at this important site in order to enlarge the fauna and to obtain additional information concerning the association of flints and remains of extinct or living species of animals.

In company with M. R. Harrington and Lieutenant S. M. Wheeler, Smith Creek Cave, north of Baker in eastern Nevada, was visited during the early summer. On the basis of plans formulated at that time, further excavation in the cave was conducted during the summer by Lieutenant Wheeler and Johns Harrington. A large addition has been made to the collection of mammal and bird remains found in the deposits. Study of this material sheds considerable light on the constituency of the late Quaternary assemblage which lived in the mountain area adjacent to Lake Bonneville basin. Important faunal and ecologic problems are involved in the investigation and special interest centers in the cave because of its elevation (approximately 6000 feet). Relationship of this fauna to the presence of Man is still to be determined. A relatively large number of bird remains have been uncovered, including special extinct types. This collection is being studied by Dr. Hildegard Howard of the Los Angeles Museum and by Dr. Alden Miller of the University of California. An extinct species of eagle has been described by Dr. Howard from this locality (Condor, vol. 37, pp. 206-209, 1935). The mammal assemblage is likewise noteworthy and a report on a new type of mountain goat found in the Smith Creek Cave deposits is now in press.

At the invitation of the Regional Officer, Branch of Planning and State Cooperation, National Park Service, Chester Stock and E. L. Furlong examined a recently discovered cave occurrence in the lower Grand Canyon in Arizona. This site possesses exceptional interest and importance because of the remarkable state of preservation of the organic remains found in the cave. The undisturbed layer of dung of the ground sloth *Nothrotherium* found on the floor of the cavern and the preservation of not only skeletal remains but of the more perishable soft parts of these animals and of others in the deposits make this site as important as that of Gypsum Cave in Nevada. It is hoped that as excavations progress and more material becomes available, opportunity will be afforded to study the organic record in detail.

In the light of the rapidly growing interest in the late Quaternary life of North America and its bearing on the history of Man in this region, it has been found desirable to review carefully the occurrence of human remains in Pit 10 at Rancho La Brea. No comprehensive study has been made of the organic record found in Pit 10 since the report on the occurrence by John C. Merriam in 1914. With this in mind, the bird and mammal remains

are being studied in detail by Dr. Hildegard Howard, Dr. Alden Miller, John C. Merriam and Chester Stock. A report of this investigation will be submitted for publication to the Institution.

*Researches of Remington Kellogg*

In addition to the "Review of the Archaeoceti," which has been completed and submitted for publication to the Carnegie Institution, progress is being made in the collection of material and in the study of the marine mammal fauna of the Miocene Calvert formation of Maryland. Among the important material obtained during the past season are skulls of the small sperm whale, *Orycterocetus*. For many years, teeth and ear bones constituted our sole record of this cetacean. Additional material representing *Eurhinodelphis* and some of the other small porpoises has been collected. A thorough study of the fauna of the Calvert formation seems particularly desirable at this time in view of the Miocene material that has been found within recent months in California. The Calvert fauna gives us a fairly good picture of the marine life of the North Atlantic during later Miocene time. When the characteristics of the various representatives of the Odontoceti and Mysticeti in this fauna are fully determined, it will facilitate a better understanding of isolated occurrences and of limited faunas found elsewhere in deposits of Miocene age. This fauna contains representatives of all the known Miocene families of cetaceans, with the exception of the beaked whales, Ziphiidæ. At least one seal and a sea-cow also occur in association with these cetaceans.

Sydney Prentice has prepared all of the illustrations included in these palæontological studies.

*Researches by J. P. Buwalda*

Field studies during the past winter advanced considerably our knowledge of the structure and Tertiary and Quaternary tectonic history of the Pasadena region of southern California. The principal faults in most of the area surrounding the Pasadena Seismological Laboratory were mapped carefully and much information was secured as to their pattern, attitude, and the character of the movement experienced by them. The faults along the base of the San Gabriel Mountains were examined and mapped for a number of miles east and west of Mount Wilson, and additional evidence was accumulated as to the mechanism of uplift of this high range. The fault pattern is very complex. Because the fractures frequently lie in homogeneous crystalline rocks, they are difficult to locate and their dip and other characters are not easy to determine. Further study will be required before many safe generalizations can be made regarding the frontal structure of the range, but it is already quite certain that the displacement on the frontal fault has been dominantly in the vertical rather than in the horizontal direction so characteristic of some of our most active faults.

In the early summer, in connection with the supervision of the Summer Field Class of the California Institute, some advance was made in our understanding of the structure and Tertiary history of the Tejon Pass region. The area is gradually being mapped with a view to gaining some

comprehension of the remarkable structures developed on the two sides of the San Andreas fault, the key to which is the deformation of Tertiary strata of known age occupying the territory adjoining the fault.

*Pluvial and Postpluvial Fluctuations of Climate in the Southwest, by  
Ernst Antevs*

In the summer of 1935 the writer studied the Pleistocene climate as revealed by the glaciation lines in the southern Rocky Mountains and the Sierra Nevada. In 1936 he is investigating the climate of the pluvial and the postpluvial epochs with emphasis on the degree of wetness and of drought and on the number and age of changes from dry to wet to dry—the amplitude and duration of the possible climatic cycles.

Knowledge of the relative wetness of the pluvial period and of the moist stages of the postpluvial is a requisite for the dating of man-made artifacts on lake beaches, in river deposits, and on river banks. It has been found that Owens Lake in California, a supposed overflow of which has been generally used as a measure of the moistest postpluvial stage, did not overflow in postpluvial time but was freshened by desiccation previous to 2000 B.C. In 1913 the lake was 29 feet deep. It has also been found that Pyramid and Winnemucca Lakes, Nevada, were freshened by overflow to Smoke Creek Desert probably about 1000 B.C., for the barriers in the Emerson Pass are alluvial fans, not lake beaches. In order to overflow, Pyramid Lake had to rise more than 20 but less than 60 feet above the level it held in 1871, which is the highest attained since white man came to the region. Walker Lake, Nevada, owes its low salinity to the fact that Walker River for part of the postpluvial, or post-Lahontan, epoch discharged into Carson River via Churchill Canyon. Thus the lakes record during the postpluvial both a drier stage and a moister stage than experienced during the past 100 years, but no decidedly wet age. Therefore, artifacts on ancient lake beaches and on now dry water courses in southeastern Arizona and southeastern California may date from the last pluvial period.

The cutting of steep-walled channels or arroyos, which since several decades takes place in the Southwest, seems to be caused by excessively rapid run-off and extraordinary erosive power of the waters of heavy rains as a consequence of reduction and local destruction of the vegetation cover by settlers and live stock. In some arroyo banks there are exposed records of several ages of deposition and erosion. In the past, arroyo cutting probably occurred after setbacks of the vegetation caused by extreme droughts. Deposition, or filling of the arroyos with sand, silt, and clay, may have occurred when the vegetation cover was sufficiently dense to reduce and check the run-off.

In some cases the occurrence of potsherds in the arroyo deposits give the approximate duration of the cycle of deposition-erosion-deposition. This holds for the beds on the Tsegi and its tributary Keet Zeel in northeastern Arizona. The cycle, to be more accurately determined from the collected material, is here a few hundred years.

The several sets of arroyo and pond sediments on the Tsegi and Keet Zeel contain organic remains including plant pollen and fresh-water molluscs.

The pollen grains in samples collected in 1935 have been studied by Professor Paul B. Sears, of the University of Oklahoma. The most important plants represented are piñon, yellow pine, ash, and walnut. The pines indicate upland, the hardwoods flood plain; and changes in their relative frequency suggest small fluctuations in moisture during the ages of deposition. The molluscs have been determined by Dr. Horace G. Richards, of New Jersey State Museum.<sup>1</sup> Three of the seven species are not known to live as far south as Arizona. However, the deep Tsegi Canyons have exceptionally cold winters. At present there are no molluscs in the Tsegi or tributaries because of the muddiness of the water.

*Studies of Early Man, by E. B. Howard*

While evidence of the contemporaneity of man and the mammoth has been brought forth from time to time ever since Koch as early as 1839 reported the finding of elephant bones associated with "several arrow-heads, a stone spearhead and stone axes," the possibility of a mistake having been made in the interpretation of these and succeeding discoveries has prevented a wholehearted acceptance of the evidence. However, new discoveries of this kind have been announced more frequently in recent years, with such finds as those at Dent, Colorado, reported upon by J. D. Figgins making these associations more acceptable.

The accumulating evidence alone has carried much weight, and now, with the finds made at Clovis this past summer, we believe the evidence is complete so far as the association of man-made objects with the elephant is concerned. Here were found, not merely one or two points, but several, including two bone points which represent the first of their kind that we know about, found with the Folsom point. These were discovered in such positions that there could be no possibility of their having intruded. One of the stone points of a type called Folsom-like rested under a vertebra, another between an ulna and humerus, where it probably rested in the flesh of the animal before it disintegrated, and still another under a scapula. A bone point was between the forelimb joints of a second elephant, and a flake knife and large scraper were found alongside the tusks. A second bone point was found in close proximity to the ribs and vertebræ of one of the skeletons.

All of these specimens rested on the top of white sand, overlain by the same hard bluish layer of sand in which other mammoth bones had been found during previous years of investigation. The site is at the same gravel pit, between Portales and Clovis, New Mexico, where quantities of bison bones and other stone artifacts had been found previously. No human remains were discovered, and we are therefore still in the dark as to how long the elephants lasted in that region, and the appearance of the men who made the beautifully flaked Folsom points.

*Studies on the Pleistocene of Florida, by Horace G. Richards*

Recent studies have been made by the writer on the invertebrate fauna of the Pamlico terrace and formation from New Jersey to Georgia. In

<sup>1</sup>H. G. Richards, *Mollusks associated with early man in the Southwest*, Amer. Nat., vol. 70, 369-371, 1936.

every locality the fauna suggests a climate at least as mild as that of today, and in many places a slightly milder climate is indicated. Because of this mild climate fauna and because of certain stratigraphic reasons, the Pamlico is thought to date from the last major interglacial stage.

During 1935 and 1936 these studies were extended into Florida. Part of the field work was made possible by a grant from the Carnegie Institution of Washington and part by a grant from the Geological Society of America. In addition the United States Engineer Office rendered considerable aid by supplying useful information and transportation.

The results of the investigation to date may be summarized as follows:

(1) At no place in Florida were marine Pleistocene fossils found higher than 25 feet above sea-level. It therefore seems probable that these fossils should be referred to the Pamlico terrace.

(2) About 200 species of marine mollusks have been identified from the Pleistocene of Florida. With very few exceptions all these species are living in Florida waters today. A few rare species are not known from Recent seas. It is possible that some may have been reworked from the Pliocene; at any rate they are very rare in the Pleistocene.

(3) Fossils were collected, either in place or from excavations at many localities along the East Coast of Florida from the Georgia state line to the Florida Keys. At a few localities, especially in the Everglades where the fossils were obtained from the spoil banks of canals, the Pleistocene species were mixed with some from the underlying Caloosahatchie (Pliocene), and it was frequently impossible to separate the two faunas.

(4) The study of these fossils supports the view that the Anastasia formation and the Miami Oolite were contemporaneous and that the Key Largo limestone represents a coral-reef deposit probably of the same age.

(5) The fauna of the marine phase of the Fort Thompson formation is very similar to that of the other marine Pleistocene formations in the State. At other places the Fort Thompson consists of a brackish and fresh-water fauna which may be younger than the Anastasia.

(6) Fossils were collected from numerous localities on the West (Gulf) Coast of Florida; the fauna closely resembles that of the East Coast and it is believed that the two faunas are contemporaneous.

(7) Pleistocene marine fossils are found at slightly higher elevations on the East Coast than on the West Coast, but never higher than 25 feet above sea-level. Leverett believes that the Pleistocene formations have been tilted down to the west because of the weight of the sediments brought down the Mississippi River. Our palæontological evidence may be taken as a slight indication in favor of this hypothesis.

(8) The 25-foot terrace of Florida appears to merge with the terrace at the same elevation in Georgia and farther north (Pamlico). This terrace is believed to date from the last major interglacial stage. Details of the evidence for this dating will be presented in a more complete report on the Pleistocene of Florida to be published elsewhere.

(9) The Pleistocene deposits higher than the 25-foot (Pamlico) terrace do not contain fossils, and it seems probable that the land stood relatively high during much of the older Pleistocene.

(10) A visit was paid to the well-known locality at Vero Beach, Florida, where human remains have been found associated with a large fauna of vertebrates, including numerous extinct species. On this visit I was accompanied by Dr. Edgar Howard of the University of Pennsylvania Museum, Mr. Frank Ayers of Vero, and Mr. M. B. Mann of Jacksonville. We agreed that the evidence pointed strongly to the fact that the human remains had been found in place and were not burials as suggested by some geologists. The bone bed (Bed 2 of reports) is younger than the Anastasia coquina and is probably separated from it by a period of erosion. In addition to the human and other vertebrate remains, bed 2 also contains shells of land and fresh-water mollusks and plant remains. All the mollusks collected from this zone appear to be living in the region today. The bone bed appears to be separated from a still younger peaty layer by another period of erosion. The coquina, as shown in this report, probably dates from the last interglacial stage. The vertebrate fauna of bed 2, with its extinct species, suggests some antiquity although it be granted that certain Pleistocene animals did not reach extinction in Florida until considerably later than has usually been thought. The erosion interval between the coquina and the bone bed may represent part of the lowered sea-level of Wisconsin time. The overlying beds (beds 1 and 2) may represent early postglacial time, during which time man may have been living in Florida associated with these extinct animals. Therefore the age estimate frequently given for "Vero Man," of from 10,000 to 15,000 years, appears to be supported by the geological data.

*Investigations on the Varve Sediments in Western Nebraska and South Dakota, by Paul MacClintock*

Studies were continued in association with C. B. Schultz, A. L. Lugn, and H. de Terra, on varved sediments in the river terraces of western Nebraska and South Dakota, which sediments in the preceding season had been found to overlie human artifacts. It was postulated at that time that the varves might be contemporaneous with an episode of glaciation and hence be of significance in dating the artifacts. The current investigation centered on the problem of whether or not varved sediments are diagnostic of glacial conditions or might have been formed at other times. Two lines of approach were used. (A) Are the varves, as judged from their stratigraphic and topographic position, of a single age and origin, and is this age contemporaneous with a Wisconsin invasion? (B) Since Wisconsin ice could have dammed tributaries to the Missouri only as far south as White River, do the valleys north of the latter contain varves, whereas those south of it contain none?

(A) One mile west of Holbrook, Furnas County, Nebraska, in a small valley, about a mile long, tributary to the Republican River, varved sediments were found. In 1894 the little valley was dammed and an irrigation ditch built across its mouth. A pond was thus formed in which water stood continuously for many years and sediment accumulated before the irrigation project was abandoned in 1904 and the dam washed out a few years later. A gully has cut into the pond deposit to reveal twenty-five varves lying on buff Peorian loess. The summer layers are dark buff silt to fine sand. The

clay layers are dark blackish-brown fatty clay which grades imperceptibly into the silt layer below (diatactic varves). Some of the clay layers have one or two silt partings in them. An unfossilized cow bone was found in the midst of the varves. Laboratory study of the varves is being made in conjunction with analyses of the climatic data of the region for the years during which the pond was in existence, to determine, if possible, whether or not the stratification is seasonal. But the case is clear that these varves were deposited in Recent Time.

One mile west of Bullhead, Corson County, South Dakota, in the valley of Grand River, a sharp stream-cut bank exposes in the material of a 20-foot alluvial terrace a lens of varved sediment two and a half feet thick and twenty feet wide. Eight varves were counted. It seems to be quite evident here that the varves were deposited in a very local pond on the ancient flood-plain during the latter's aggradation.

In the loess canyon district of Lincoln County, Nebraska, valleys, tributary to the Platte River, contain two aggradational alluvial terraces; one at fifteen to twenty feet above the present valley flats, and the other at forty to sixty feet. In Snell Canyon and Conroy Canyon, varves were found in the lower terrace. On the other hand, in the valley of Sand Creek, a tributary to the White River in Dawes County, Nebraska, the varves occur in the upper 40-foot terrace. So long as the terrace history of the region is not known with confidence, evidence is not yet at hand to assert that the varves are all contemporaneous, and when the occurrence of very recent varves at Holbrook is recalled it seems that until more is known about varve formation, they are scarcely a safe criterion of glacial time.

(B) From the occurrence of varves along the Republican and Platte Valleys, neither of which was dammed by the Wisconsin ice, it is obvious at once that damming by a glacier is not necessary for their formation.

And, furthermore, a reconnaissance of western North and South Dakota west of the Missouri River, particularly the valleys of the Cheyenne, the Bad, the Moreau, the Grand, the Cannonball, and the Heart Rivers, failed to reveal deposits of varved sediments such as should have been formed had Wisconsin ice advanced into the eastern ends of these valleys. A still more striking bit of evidence against ponding is found in the Missouri valley, five miles southeast of Pierre, South Dakota. Here a rough, bouldery moraine of obvious Wisconsin age descends from the upland down into the valley to within thirty feet of the present flood plain. This seems to be conclusive proof that the Missouri River had cut its valley here to at least its present depth in pre-Wisconsin time.

*Summary*.—Varves may be of different ages. They were formed during episodes of valley aggradation; possibly times of increased precipitation when water stood in flood-plain lakes throughout the year. This suggests a glacial or late glacial climate but does not prove it. But if the aggradation could be shown to have been at least partly caused by the aggradation of glacial valley trains in the Missouri and Mississippi, the varves might still have chronological significance.

**deTerra, H.**, Museum of the Academy of Natural Sciences of Philadelphia.  
*Studies of geology, palæontology, and archæology relating to the origin and evolution of man as it may be recorded in the Himalayan region of Asia.* (For previous report see Year Book No. 34.)

The expedition party, under the leadership of Dr. H. deTerra, remained in India from February until December 1935, expenses being met in part by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington. The program was carried out according to plans—thanks to the cooperation of the various staff members and to the help of Government officials. The major task of this study was achieved since the party secured a large collection of prehistoric implements, which give evidence of man's evolution in India from the middle of the Pleistocene period until historic times. The uniqueness of the research field, which provides for a complete geologic record from the Pliocene period on, enabled the expedition to work out a standard sequence of geologic events by which it was possible to date the pre-human anthropoid evolution as well as the range of Palæolithic cultures. Ice Age and mountain-making records, changes of animal life and of river systems, provided material for the study of geologic environment in which early man evolved from a primitive Stone Age culture to a stage in which the oldest Indian civilization is rooted.

#### EXPEDITION ITINERARY

As previously reported (see Carnegie Institution of Washington Year Book No. 34, 1934-35, pp. 319-321) the expedition members studied the glacial history of the NW-Himalaya in Kashmir during the summer. This survey involved a stretch of country extending from the slope of the main Himalayan range across the Kashmir Valley and the Pir Panjal Range to the lowlands in Jammu and Poonch. With the knowledge gained from this mountainous tract, it was possible to correlate the Pleistocene formations of the adjoining plains with glacial and interglacial deposits in the Himalaya, and thus a key was found to date the prehistoric cultures entombed in the fluvial outwash formations of the Punjab.

On September 27, Dr. Teilhard de Chardin joined the other members and a series of joint excursions was made in Kashmir and in the vicinity of Rawalpindi. The first half of October was spent in studying important exposures of Plio-Pleistocene formations in the eastern Salt Range. Mr. T. T. Paterson, assisted by Mr. J. Drummond of Cambridge, England, extended these surveys toward the Indus River tract. Teilhard and deTerra visited a number of Pleistocene basins and explored the implement-bearing loess and gravel deposits of the Soan Valley. In the first week of November they excavated a bone bed of early Pleistocene age near Campbellpore and they unearthed later in the Soan Valley the oldest (Chellean-Achenlean) culture so far found in the Himalayan foothills.

As it was advisable to test the correctness of their opinions on Pleistocene geology and human prehistory, the four expedition members spent the last month in visits to various places of interest. Teilhard and deTerra went to Upper Sind where Mousterian to Neolithic cultures were located near Sukkur and Rohri. A brief visit to the famous ruins of Mohenjo Daro proved



fruitful in many respects. From here the members returned to Rawalpindi to supervise the packing of collections. In December, Teilhard and deTerra surveyed briefly the Pleistocene along the Narbadda River in Central India. This region proved to be especially interesting on account of the close association of early Palæolithic implements with fossils of middle Pleistocene age. This makes the Narbadda Valley equally important as the Himalayan foothills as far as man's evolution is concerned; in fact it seems to be a most promising field for any future search of human fossil remains. Messrs. Paterson and Drummond carried out field work in Madras and studied the more important collections of prehistoric implements at various Indian museums.

#### BRIEF REVIEW OF EXPEDITION'S RESULTS

*Palæontology*—In this field the expedition secured some 1100 vertebrate fossils of the late Cenozoic in India. Among these is a collection of 24 remains of man-like apes, the largest number which has so far been collected from the Siwalik formation. The study of this interesting material was entrusted to Professor W. K. Gregory of the American Museum of Natural History, who is assisted in this work by Dr. M. Hellmann and Mr. G. E. Lewis. For the first time it has become possible to reconstruct complete dentitions and certain facial features of such forms as *Palæosimia*, *Dryopithecus*, *Shivapithecus* and *Ramapithecus*. These man-like apes represent the critical stage of anthropoid evolution during which the evolutionary trend toward man became accentuated. It is probable that a climatic change from a tropical to a cold and semi-arid habitat is responsible for this event and that man evolved at the close of the Pliocene period from an anthropoid ancestor related to *Ramapithecus*. The bulk of the Siwalik fossils will be studied by Dr. Edwin H. Colbert of the American Museum of Natural History, who on previous occasion has become well acquainted with the Siwalik fauna.

*Prehistory*—The oldest and most primitive human implements appear in India at the close of Siwalik time, e.g. during the middle Pleistocene. The antiquity of this culture rivals that of Peking and Java man and it can therefore be stated with confidence that India was not only a center of anthropoid evolution, but a home of the most ancient hand-ax culture. Over 4000 stone tools were collected and the occurrence of the Chellean hand-ax culture was proved from the Himalayan foothills across Central India to Madras. On typologic grounds, it appears that the Clacton and Levallois industries of the European and African Palæolithic were also well developed in India and that the hand-ax culture persisted here into the late Palæolithic and Neolithic. The Chelleo-Acheulean implements found in the Narbadda valley of Central India resemble the newly discovered early Palæolithic in Java. The Upper Palæolithic and Neolithic of India, however, points to prehistoric relations with Asia Minor and Africa, especially so far as the Capsian industry is concerned. The collections were temporarily placed in the Archæological Museum at Cambridge University where they are studied by Mr. T. T. Paterson, under supervision of Professor Burkill. They will eventually be distributed between Yale and Cambridge University and the Indian Museum.

*Geology*—An outstanding and hitherto unsolved question in the geology of this region was the age of the Upper Siwalik formation and the definition of the Plio-Pleistocene boundary. In this respect the expedition has gathered sufficient evidence to show that the Upper Siwaliks are throughout of Pleistocene age and that their oldest deposits rest disconformably, often unconformably, on Pliocene rocks. The fossil fauna shows Pleistocene affinities and the top beds, called "Boulder Conglomerate," merge at places with moraines belonging to the second glaciation. The glacial cycle in Kashmir is represented by four major sets of moraines indicating a four-fold glaciation and three interglacial periods. Three major orogenic phases became discernible to which the region owes its profound geographical changes. It is estimated that the sub-Himalayan range was uplifted by some 5000 feet since the close of the first Interglacial. This mountain-making activity influenced the local character of Pleistocene glaciation which gained in intensity in the southernmost range as uplift progressed. Hence an unusual opportunity was found to study the orogenic control of mountain glaciation. Loess deposition was connected with the third and later glaciations, and it is under these various types of loess that the prehistoric cultures were found. A Pleistocene monsoon climate with heavy seasonal rainfalls led to deposition of what might be called "pluvial loess."

The geologic work provided principally the basis for the multiple study of Early Man and it demonstrated the continuity of mountain making at the time of prehistoric man's earliest achievements.

Publications are under way relating to the various subjects of study. deTerra and Paterson are preparing a large memoir on the "Ice Age in Southwestern Kashmir" and on "Early Human Cultures in India."

**Campbell, Ian,<sup>1</sup> and John H. Maxson,<sup>1</sup>** California Institute of Technology, Pasadena, California. *Geological studies of the Archean rocks at Grand Canyon.* (For previous report see Year Book No 34.)

Field work on the Archean rocks of the Grand Canyon was continued during the fall of 1935. Reconnaissance studies were extended as far east as Grapevine Creek, thereby practically completing, for the Bright Angel Quadrangle, the reconnaissance geology on the south side of the Colorado.

The greater part of this year's work, in contrast to the essentially reconnaissance work of previous seasons, was devoted to detailed mapping, centering around the Bright Angel-Phanton Creek, Lone Tree Canyon and Clear Creek sections. The construction of a new trail on the south side of the Inner Gorge, from the mouth of Pipe Creek to the suspension bridge, afforded excellent new exposures of the Archean rocks typical of this section. A geologic map of this trail on a scale of one inch to forty feet was constructed by pace and compass traverse. Not only does this map allow exact location of "type" specimens, but the geological detail which can be shown permits a far more accurate understanding of these rocks than heretofore. It also makes possible a reasonably accurate estimate of the relative amounts of different rock types exposed in this section. The new Clear Creek trail,

<sup>1</sup> Balch Graduate School of the Geological Sciences, California Institute of Technology, Pasadena, California.

connecting Bright Angel Creek with the Clear Creek basin, although not mapped in the same detail, also provided new and interesting exposures.

Many oriented specimens were collected from which it is hoped to obtain, by petrofabric studies now in progress, additional and more exact information on the structural relations between the schists and the granites and pegmatites intrusive into them.

Perhaps the most interesting single discovery of the season, with respect to interpretation of Archean history, was the finding of a "pillow basalt" in the Clear Creek section. The original rock has been metamorphosed to an amphibolite, but recrystallization has not entirely obliterated a well-marked ellipsoidal structure. That this rock, occurring as it does above a section of quartzites and meta-argillites (garnet and garnet-staurolite schists), represents a submarine extrusion of basaltic lava seems altogether likely. Previous to this discovery, structures which had been tentatively classed as metamorphosed amygdules had been found in the amphibolites exposed in the new south side trail section. Both lines of evidence (ellipsoids and amygdules) point to these Archean amphibolites as having probably been basaltic flows rather than intrusive bodies.

The striking Archean monadnock (easily visible from the Yavapai observation station) which lies just west of the Clear Creek basin was investigated in some detail. The greater part of this structure consists of a rather massive, medium-grained, muscovite-biotite-granite. Surrounded by weaker schists (amphibolites and meta-sediments) and constituting as it does one of the largest bodies of relatively massive rock in the Archean section, its topographic expression is easy to understand.

The granite itself is well exposed by the narrow canyon of Zoroaster Creek, while the contact can be seen best where exposed on the south side of the Colorado gorge, across the river from the main exposures of the monadnock. The structure seems to be definitely intrusive, the granite contact cutting across, at a steep angle, the nearly vertical schistosity of the country rocks. The name "Zoroaster granite" has been tentatively applied to this body.

The Archean history of this general section, fore-shadowed in previous reports and now gaining in clarity as a result of the detailed work of the present season, is approximately as follows:

**FIRST:** Deposition—upon a terrane still virtually unknown—of some thousands of feet of sediments, chiefly argillites and fine-grained sandstones. Toward the end of this period of sedimentation, volcanism became active and near the top of the section basaltic lavas were intercalated. Some of these flows very probably took place as submarine extrusions.

**SECOND:** A period of dominant volcanism, in which certainly many hundreds and quite possibly some thousands of feet of basaltic lava accumulated. Sedimentation was interrupted but not obliterated, and sandstones and argillites were deposited in at least small amounts at intervals throughout this period.

**THIRD:** Intense orogenic disturbance (Arizonan of Hinds) whereby the sediments and lavas were strongly folded and very considerably metamorphosed.

**FOURTH:** Perhaps concomitant with the declining phases of the orogeny, and very likely continuing after it, came intrusions of granitic magma, forming such bodies as the Zoroaster and Phantom granites and giving rise to numberless smaller dikes and to such phenomena as granitization in the meta-sediments, production of migmatites, etc. The last event of the intrusive period is represented by the intrusion of abundant pegmatites, many of which develop lit-par-lit structures in the schists. The pegmatites together with the granite are responsible for additional metamorphism of the meta-sediments and lavas.

**FIFTH:** Ep-Archean erosion.

From the information at present available it can be little more than conjectured—although the suggestion seems at least worth making—that the center of extravasation of the lavas may have coincided with the axis of a subsiding geosynclinal trough in which the Archean sediments were being accumulated. It is significant, too, that one of the main centers of plutonic intrusion seems to have been along this same axis. For this reason, perhaps a majority of the migmatites consist not of granite and meta-sediments, but of granite (or pegmatite) and amphibolite. Also in this same portion of the area (*viz.* the Bright Angel, Pipe and Garden Creeks section) is found some of the most abundant faulting, including Archean, Algonkian and post-Palæozoic disturbances.

Two short trips were made during the spring of 1936, to the vicinity of Pierce's Ferry, at the upper end of Lake Mead. What are presumably Archean rocks were reconnoitered in the section below Iceberg Canyon and also in the lower Granite Gorge. It appeared that the rising waters of the lake behind Boulder Dam are not likely to obscure any significant exposures of these Archean rocks and it was accordingly decided not to prosecute work in this vicinity until the mapping is farther advanced in the Grand Canyon section.

Negotiations have been completed with Fairchild's Surveys, Inc., whereby three of their specially constructed "Colorado River" boats were purchased, to be used in an expedition down the Grand Canyon from Lee's Ferry. This expedition was originally planned for the fall of 1936, but due to a year's leave of absence for work for the Turkish Government, obtained by Dr. Maxson in the spring of 1936, the expedition has been postponed until the fall of 1937.

It is a pleasure to acknowledge the assistance received from Mr. Schenk, Mr. Clarke and Mr. Evans and the men working for them in one of the E.C.W. units of the National Park Service at Pierce's Ferry. Dr. F. D. Bode, Dr. H. J. Fraser and Mr. Luis Kemnitzer of the California Institute of Technology and Mr. Frank Dodge of Lee's Ferry have also been of material help in certain phases of the work.

**Hinds, Norman E. A.,** *Researches on Algonkian formations at Grand Canyon National Park.* (For previous report see Year Book No. 34.)

Field studies of the Algonkian strata at Grand Canyon were continued during June 1936. Laboratory and office work on the Unkar division has been carried on during the year by C. E. Van Gundy, who is making a

special study of that group, while my time was devoted to the Chuar division and other Algonkian problems. Preparation of maps, study of collections and writing of the report are well along.

In 1935, Mr. Van Gundy found a beautifully preserved fossil in the quartzites of the Nankoweap (middle) division of the Algonkian which are exposed only in the eastern part of Grand Canyon; this fossil was submitted to Dr. R. S. Bassler who identified it as a jelly-fish. Careful search for other fossils by Mr. Van Gundy in the Nankoweap and Unkar divisions and by me in the Chuar division was unsuccessful. This summer I devoted most of the field days to a careful bed-by-bed search in the Unkar sections. Definitely identifiable remains were not found, but some of indeterminate sort I am submitting to authorities on early Paleozoic life. Doubtless a few fossils are present, but so widely scattered are they that discovery is the merest chance. Except for the supposed algal limestones, the jelly-fish is the oldest fossil from the Grand Canyon section.

Further observations were made in southern Arizona to determine the age of the diabase intrusive into the Algonkian Apache group. In the Mescal Range and near Superior, Ransome and others<sup>1</sup> have held that the diabase is intrusive into the Middle Cambrian Troy quartzite as well as the Apache group. Careful field study shows, however, that, at the surface in the vicinity of Superior, the diabase is not intrusive into the Troy. In certain places near this camp, the Troy rests on an erosion surface cut in the diabase, and debris from this rock is incorporated in the basal Troy. Where not resting on the diabase, the Troy is in contact with the Apache Mescal limestone or basalt which also belongs to the Apache sequence. In the Magma Mine at Superior, Short and Oettlinger<sup>2</sup> believe that the diabase is intrusive into the Troy, though they admit that the quartzite in question may be the Apache Dripping Spring or that an older and a younger diabase may be present. The workings where contacts and xenoliths encased in the diabase are visible no longer are accessible. Elsewhere in southern Arizona, I have seen no place where the diabase has invaded the Troy, and Darton<sup>3</sup> indicates that the contacts of the Troy and diabase in the Mescal Range are erosional rather than intrusive as Ransome thought.

Some search for fossils was made in the Apache sediments, but without success; more intensive examination should be made.

Further brief examination was made of the Uncompahgran Mazatzal quartzite near Del Rio and near Fort Defiance, Arizona, and of the Uncompahgran Cottonwood quartzite in the Wasatch Mountains, Utah.

Objection must be filed against the recent statement by Stoyanow<sup>4</sup> that "if a provisional correlation of the Algonkian of northern and southern Arizona is desired at this time, the unconformity between the Unkar and Chuar, noted by Walcott, and that existing between the Mazatzal (Mazatzal quartzite of central Arizona) and the Apache (Apache group of central

<sup>1</sup> F. L. Ransome, Ray Folio, U. S. Geological Surv., Folio 217, pp. 10-11, 1923, and other papers. E. N. Harshman, Personal communication.

<sup>2</sup> M. N. Short and I. A. Oettlinger, Personal communication.

<sup>3</sup> N. H. Darton, *A resumé of Arizona geology*, Univ. of Ariz. Bull. 119, pp. 33-34, 1925.

<sup>4</sup> A. A. Stoyanow, *Correlation of Arizona Paleozoic formations*, Bull. Geol. Soc. Amer., vol. 47, pp. 473-474, 1936.

and south central Arizona) can be used as a basis." The Mazatzal thus would be the correlative of the Unkar and the Apache of the Chuar group. As I have shown elsewhere,<sup>1</sup> the Mazatzal is a pre-Algonkian series to which the tentative time name Uncompahgran is applied. After the deposition of this quartzite, it was folded into mountains, deeply eroded and removed over considerable areas from the Archean basement. Débris from these strata is present in the basal Apache conglomerates in south central Arizona and in the basal Unkar conglomerates at Grand Canyon. Before Algonkian deposition started, therefore, the Mazatzal Mountains, as I have termed the product of this orogeny, were erected in central Arizona and formed a barrier separating the Apache basin of southern Arizona from the Grand Canyon basin of northern Arizona. If correlation is to be made, the Apache beds most closely resemble the Unkar beds at Grand Canyon where the Mazatzal strata are not represented. The latter are quite unlike the Unkar. The Apache sequence in no way resembles the Chuar; the latter apparently have no correlative in southern Arizona. The unconformity between the Apache and the Mazatzal is in no sense the equivalent of the slight disconformity between the Nankoweap (formerly Upper Unkar) and Chuar divisions at Grand Canyon.

Another point of less value is that diabase was intruded and basalt erupted following deposition of the Apache and Unkar beds, while no rock of these types is present in the Mazatzal or Chuar sequences.

A chart showing my present opinions regarding correlation of some of the pre-Cambrian formations in western North America is given on pages 132 and 133 of the article referred to above.

**Wieland, G. R.**, Yale University, New Haven, Connecticut. *Cycadeoid investigations and field work*. (For previous report see Year Book No. 34.)

It is again wished to briefly advert to what is for convenience called the monomorphic view of plant descent. As cycadeoid investigations have turned out, that is taking them in their entirety and with the more acute studies of the cycads as carried out especially by Chamberlain, there has come into view a much vaster ancient cycadeous vegetation than the evidence assembled during the first century of the science of fossil plants could by any possibility have implied. It is seen, moreover, that not only was the Jurassic an age of great flowering plants, but by inference the Triassic as well. As this later evidence for the antiquity of floral structures and the great rôle of the inflorescence in Paleozoic times comes into clearer view, it is seen that far back in time the several gymnosperm lines, whether we take the view of somewhat separate origins or not, had much in common in all their main features. Thus, the outlines of the cycadeoid flower had no sooner come into view than it became possible to predict the discovery of the seed ferns. While at present, except for the slight advance in wood structure toward the pines seen in Ginkgo, we see in that old type nothing but a Cordaite. And too in cycads and cycadeoids there is not in foliar, stem, staminate or carpellary

<sup>1</sup> N. E. A. Hinds, *Uncompahgran and Beltian deposits in western North America*, Carnegie Inst. Wash. Pub. No. 463, pp. 53-136. 1936.

structures a single post-paleozoic feature—unless bar one, the disk of stamens. But that easily formed, and there is the erectly borne seed, the simple stalked carpel so alike in Ginkgo, the Cordaite *Samaropsis*, and the cycadeoids. In both Ginkgo and the cycadeoids we see how easily these stalks may increase or decrease in number and that they readily become sterile or fuse. The latter fact suggests the nature of the initial change leading into the cones of the conifers.

Especially the wood structure of the cycadeoids is old and generalized though nevertheless presenting a most remarkable approximation to the wood of the homoxylous angiosperms. Therefore, not forgetting the two-cotyledon embryo, noted in ginkgo as well, in this broadened view of seed-plant beginnings a vast antiquity must be assigned to the angiosperms, and they become from all severe points of view a part of the primitive, much related seed-plant alignment. That older opposed view of a derivation of the higher seed-plants from the extraordinarily conspicuous Lepidophyte complex of the Paleozoic has indeed again come to the fore as a sort of by-product of investigation during the past few years. Studies of the cone morphology suggest within certain narrow limits lepidophyte derivation. And this seems to have led to the suggestion that the highly specialized condition in *Juniperus*, where stamens at last subtend seed scales, may indicate a sub-angiospermous stage. All this seems very inadmissible.

For an extremely cautious and yet vivid survey of the foreground here, D. H. Scott in his extinct "Plants and Problems of Evolution" of the year 1924 should be cited, while in that same year there was brought out in the course of our studies a simple notation of persistence and occurrence in the vegetation of the past from the viewpoint of ordinary arithmetic. A few years later it was sought to further synthesize views of the relative antiquity of the angiosperms; and then came very late in the day, it must be admitted, the great display of free-flowering cycadeoids from the Mesaverde of the San Juan Basin. True enough in some three tons of this material, now extensively cut for both larger and lesser features marking three new species, there is, beyond a most imposing demonstration of type, nothing new to the cycadeoids as a group. Robert Brown said a hundred years ago that the stems had buds in all the frond axillæ. And the wide-spread existence of such a special feature group on both sides of the Atlantic has been well attested for thirty years, including as it does that marvelous fossil *Cycadeoidea Dartoni*. But even yet, will mere weight of evidence be enough to convince the doubting of the fact that here are very ancient forms become specialized to the point of abnormality? Yet, they are related to the freely branched types with larger flowers; they invite attention to both the flower and the inflorescence as axes of limited growth. We see again that whether the ancestral seed plants were large or small, megaphyllous or microphyllous or, both as more likely, leaf and floral organ were always subject to much change of form within given groups, while fusions in flowers and cones are not alike but merely apposed, and certainly there must have been present somewhere during the early upward stages in seed plants the *Urpflanze* of Goethe.

From thence on we must not trust the geologic record taken *per se*. Instead it is necessary to turn toward casual discovery awaited in certain more favor-

able horizons like the Jurassic series of India and Mexico, and many Rhætic localities of Chile and Argentina. And besides arithmetic, we must consider every possible item in the more assumable course of change from canopy to canopy. In particular we need to note features of cauliflory, proliferation, the appearance of axillary growth, and regeneration with respect to the development of branching systems; while specialization and late deployment of type as a quick reaction to new geologic environment must not be taken for origin—they may be the prelude to extinction. Nothing has so much obscured ideas of the origin of the angiosperms as the relatively late development of dicot net venation as certainly coordinated with the change in tracheidal balance and size ending in the ring-porous and diffuse-porous wood types in endless variety of species, along with extreme branching and giantism. Yet many of those types must have been small flowered far back in time, changing in their floral features relatively little for ages. Sterilization, branching, leaf-floral change, and giantism are the primary factors in environmental response. With these go the subtler specific changes that may lead to a run-oak of the stony barrens with large seeds or to the grand avenue of small seeded Pakenham Oaks of New Orleans. Also, there has been too much stress laid on leaves, perhaps because there is *style* in their preservation as fossils. It is very overawing to find in Rhætic floras, those of just the period in which much change is hypothesized, such a worldwide similarity of type, until we bring the facts of chemistry and arithmetic to bear. Then the further possibilities come into view. The plastic types of the upland and plateau vegetation of the past must seldom find record as fossils.

Also what may be termed the behaviorism of plants should have some consideration. For instance the cause of the multiple inflorescence, whether due to recessiveness or regeneration due to injury, is worthy of a thought. Similarly, one of the most singular abnormal types of cone branching seems hitherto to have been overlooked. Chamberlain recently called my attention to the presence of multiple branching in ovulate cones of *Zamia floridana*, and very soon thereafter I found perfectly and even freely branched staminate cones in *Cryptomeria japonica*. To say the least with such possibilities of growth in view, the rôle of the inflorescence seems less strange, the fact that we see in the magnolias the transitional floral and branching features the more impressive.

What has just been put in discursive form perhaps gains a certain emphasis as the result of the field work at Fossil Cycad National Monument last November. Then, as I was able to arrange through the Bureau of National Parks and Monuments and with the aid of CCC help on the monument front, about one ton of *in situ* cycadeoids was secured. As had been hoped might prove true, this material is particularly rich in the small and branched species like the *Cycadeoidea nana*, and especially the *C. protea* and *minima*. These are the types within the transition from the large-stemmed group to freely branched small-stemmed types, like *Wielandiella* and *Williamsoniella* by way of *Williamsonia*. In much of this new material the leaves are very small, and the fruits also, as already proven from cutting. These meaningful lesser types, hitherto known only from broken or eroded specimens, now become among the best known. Such a result directly from the field is



new in cycadeoid investigation, this being the first time that the petrified forms have been quarried for direct.

Moreover the high value of the Monument is now demonstrated beyond all cavil. Not only is the material already secured and assembled ample for a great display of the entire range of feature in the petrified series, but all results of excavation point to the presence of much more material on the cycadeoid level, which extends entirely through the mesa capping of the great locality within easy reach of further excavation. Now that the relations are closely established by actual excavation bringing into complete view all conditions, it is seen in fact that according to all law of chance the level of the material as it runs directly along and across the mesa should yield a very rich additional store of the uneroded and complete stems. In short the proposal to place a small but extremely simple well-constructed field museum near the point on the mesa cap where the type *Cycadeoidea superba* was secured in undisturbed strata proves defensible from every point of view. This location reveals a marvelous and scarcely paralleled drama of geologic, chemic, and biologic change begun long ago in dinosaur times, and the estimated cost of appropriate means of exhibition is small when the high educational and æsthetic values are duly considered. Rightly done, in utter dignity with all omitted that would tend to clutter or render the results obscure or nondescript, this gesture would surely win the acclaim of student and traveler alike for a thousand long years. If any further defense of such a display be needed, let the fact be emphasized that it means the exact opposite of anything like a narrow localism. The more continental our interests, the more certainly may social and political unity be achieved.

In regard to the subject of species in the cycadeoid petrified series it is noted that infinitely the more important study phase refers to the interpretation of the group. A survey of the subject has been given in the recent account of the Carpathian cycadeoids. It is found that no greater mistake could be made than the heedless proposal of new species or the haphazard untimely meddling with so-called "revisions." In a group like this it is of little moment to recite features which an author himself might never again use and no one else note. However, in the fine Mesaverde group, so well understood from occurrence in the field, and now cut extensively as a preliminary to illustration mainly done, there are present three species and no more. The first is the species, using an expressive generic characterization, *Monanthesia magnifica* (cf. fig. 48, Cerro, Cuadrado Petrified Forest). This is the form of abundance and large size, a foot and a half in diameter and reaching four or more feet in height.

The second Mesaverde form is *Monanthesia blanca*, closely related to the foregoing, and represented by but a single though very finely petrified specimen so far. The curiously interesting armor section has been illustrated in at least one botanical textbook. While the third species as placed near both the preceding is perhaps a smaller more ovaliform stem type with markedly smaller leaf bases, hence conveniently distinguished as *Monanthesia æqualis*.

Related to the foregoing but without a sign of axillary bud or fruit growth is an isolated specimen only known to come from somewhere in Montana. In this instance at least there is no choice but to give eventually a new

specific name; but a name has been most carefully avoided so far because the locality may be found and other more diagnostic materials recovered. Moreover this is an indicated likelihood since certain occurrences of the pseudo tree-fern *Tempskya* (related to the existing *Hemitelia*) have been coming to light in Montana. Similarly a curious stem cast from the "Temblor sandstone" of Kern County, California, has been examined with needed care. A recommendation that it were better to wait than refer such a specimen to the form genus "*Bucklandia*" with the implication of a cycadeoid relationship extending into very recent times proves doubly justified, as this is probably a sisal plant not unlike types growing in Lower California today.

The cycadeoids of the Trinity Beds of Texas mentioned in Year Book No. 30 and also in *Science* present fairly distinct specific variation and have been preliminarily referred to five new species. Four of these (*Cycadeoidea Boeseana*, *C. Barti*, *C. Johnstoni*, and *C. Wolfei*) are low-growing or ovaliform, non-columnar types with scattered fruit growth, all going to suggest little variation in form or geologic age from the species of the Maryland Arundel. But a fifth species is noteworthy as a branched stem at first referred to *Cycadeoidea*, though better called *Williamsonia Dyeri*. About a foot high, but not nearly so heavy stemmed as the usual Cycadeoidean type and distinctly branched several times in Y-form, this specimen is even remarkable. It would also relate itself to a columnar stem with very small leaf bases noted in the new *in situ* material recovered at Fossil Cycad National Monument. To find these complementary, intermediate features, to get such supplementary materials is assuredly a source of much satisfaction. The lesser specimens from the Monument to which so much interest attaches are referred to *Cycadeoidea minima* and *C. protea*, and to *C. nana*. Illustration of all this material is already in hand.

Gradually as these investigations go on we are thus brought to simpler and simpler points of view. It does seem that finally there may be visualized the approximate relationships in the ancient canopies, the actual rise of the Anthostrobile as the flowering plants may be called, taking them in their somewhat geologic totality. There is no longer any great or impassable hiatus in either stem or foliage in the way. Nor is there a final floral difficulty. As the evidence now stands, however, the strange similarity of the stalked, erectly borne seeds in Ginkgo and the Cycadeoids presents a sharp difficulty because of the excessively long time it has endured. Extreme aplasticity such as that does not seem to help much in visualizing the change toward the carpel. Yet, we must think of these as leaf-borne seeds. Or in other words there is true and extremely ancient relationship between the cycads and the cycadeoids on the one side and the Cordaites on the other, as all three groups come up from the seed ferns; while it is certainly likely that the greater group Coniferophyta is an off-shoot from the Cordaites—if not, their origin must be sought among the Lepidophytes—the opposed polymorphic view.

How difficulties of interpretation may resolve themselves is nicely illustrated by the large sections through the cortical region in the monocarpic stems. The bundle course, origin on the woody cylinder, and formation of

the leaf-base and peduncle patterns all stand out diagrammatically clear. Because all the features are present on a very large scale as compared with what would be seen in stems with a thin cortical zone as in seed plants generally, a curiously instructive picture is afforded. Especially, the analogy to be noted in the larger cones of the conifers invites attention. At first sight it might be thought that the cycadeoid frond bundle as it springs from the lower angle of the leaf gap is an exact opposite of the bract bundle of the coniferous cone which merely subtends the scale bundle as it arises directly on the cone cylinder. However, some further consideration here teaches us that in a sense a frond is a branch, and a bract too. Also the seed-scale is a branch in exactly the same sense as the cycadeoid flower. Both are confined to the reproductive function, but nevertheless represent a regeneration of the primary axis; and that axis has the power of adventitious or cauliflorous growth delayed even for years. In a cycadeoid with storage of food supply, as fruiting sets in, whether seasonal or monocarpic, further growth of the bundle systems occurs along the sides of the leaf gaps, and the two heels of the primary leaf-base horse-shoe bundle do in a sense seem to be the growing points. But if the cortex were thin, this long course of bundles at first fused and then free would not be seen. Instead there would appear merely a short bundle supply to an axillary bud.

I attach much significance to the exact geologic conditions at the Fossil Cycad National Monument front, not alone from having searched there through the years, but also from having come to appreciate the fact that a vast amount of material has been eroded away, or merely carried away by the curious. The conditions are relatively simple with respect to the occurrence of the specimens along the Mesa front and across the Mesa, northerly from a line of slip and slight faulting which has long been recognized. Three specimens (as well as many others) long since collected and illustrated as among the most remarkable ever recovered proved the general conditions. The first lay in its original relation to the Thirty Foot shale, at the top of which the specimen was covered by the somewhat laminated sands which succeed as the mesa capping. But it was clear that faulting, or slipping, also had occurred. The second fine specimen of the three, a singularly handsome and complete branched stem of a different species, was excavated near the eastern end of the outcrop, the same conditions again recurring. While the third, the type of *Cycadeoidea superba*, came from the undisturbed mesa capping, proving with many other specimens that the area of occurrence persisted. In the recent excavation resulting in the recovery of so much fine material, all these points are fully verified. The line of slip along the front carried down so many specimens that an early local collector supposed the specimens nearly all came from near the bottom of the south ravine of the Monument. But many specimens came from the eroded edge of the mesa cap, as well as from clear across the mesa. Also our blasting of last November uncovered several such, while despite the search and specimen hunting of forty years along the mesa front fragments were yet to be found on the main open level. In short, the original, somewhat ovaliform area of abundance has for a long diameter the mesa front for about 1500 feet, as partly conditioned by a small fault of a few feet, slip, and erosion. Naturally these

conditions might lead one observing superficially to the idea that little more material could be had. But this is the exact opposite of the truth. A large part of the ovaliform area of abundant specimens yet remains undisturbed and within the line of easy excavation.

About half a mile easterly there is a stream channel to be seen along the "AYP" highway noted in 1927 as cutting into the same shale as that on which the cycadeoids rest. Therefore it is clear that as the deeper lake waters in which this thirty-foot shale was deposited, shallowed, a low-lying valley marked the area along which the cycads lived and could readily be silted over by the sands and clays which then began capping the shale bed. A hot semi-arid climate and spring floods are indicated. As the specimens often rest on or partly in the shale, it is possible that some at least are now found where they grew on sandy low flats, subject to Nilotic flooding. But others are prone and flotation along the line of arenaceous silting-in may be for such the first explanation. In any case the conditions leading to the lignitic stage as the absolute prelude to petrification only extend through the first foot and a half above the shale approximately, and there is no such positive proof of old soil as at the famous "Dirt Bed" of the Isle of Portland.

After lignitization, the next great event was the formation of another fault along the line of the Chilson Cañon with the welling up of thermal, orthosilicic acid-laden waters which must have made their way laterally over the thirty-foot shale to the cycads and petrified them. The presence of such waters and of such a slight fault or tension line is testified to by an upright more or less ragged sheet of chalcedony from a half to a foot in thickness, traceable for some distance just easterly along the Chilson trend. The stems could lay a very long time with little change. A small but characteristic lignitized cycadeoid was found in the Raritan of New Jersey and recently described by M. A. Chrysler. Curiously enough, it is certain that the large flower buds of the magnolias have the plant texture which should make it possible for them to resist decay, reach a lignitic stage, and afford objects of petrification study. The uniformly sharp features of the *in situ* cycadeoids with frequent projecting fruits all invested directly by iron-coated or soft sands indicate that "petrification" follows extremely well-defined chemical reactions, rather than being a mere resultant of the deposition of amorphous silica.

In earlier Year Book reports mention was made of the petrified dicot stems accompanying the conifers and cycadeoids along the Chuska Mountain front. These are well silicified, and mark at least two distinct species of Lauraceous trees of medium to large size. As stated above, the cycadeoids include three distinct species—while there is another form near related to the Maryland Arundel species *Cycadeoidea Fisheræ*, but which may have come from a somewhat different horizon in Arizona. The conifers are of varied specific type, determination of these particular species not having been taken up.

In addition there was brought in by a Navajo in 1928 a small but characteristic portion of a stem of the curious pseudo-tree fern *Tempskya*, above mentioned. While in the same general locality about the old "Mexican Springs" trading station I too found in 1928, imbedded in a large mass of weathered-out sandstone ledge, an entire frond crown of a large palm. Since then, Professor F. B. Loomis of Amherst, working in the same locality, found a

beautifully silicified portion of a palm stem of large size. This was referred to me for identification, and has been sectioned. It belongs to the section of the *Palmaceæ* with interspersed bast strands.

Professor Loomis is to be congratulated on having made such a fine and much wished find—finally indicating that the Mesaverde includes the most remarkable series of petrified types of any single western horizon. For here is now seen an assemblage including five greater groups of plants, the conifers, dicots, cycadeoids, palms, and true ferns, all silicified in absolutely diagnostic form.

The wedge sawn from the great Dresden cycadeoid "*Raumeria*" as dissected and described several years ago has been finally returned to the custodians of the Zwinger Museum, and they announce their satisfaction with the results from both the scientific viewpoint and that of exhibition. Likewise they express their deep interest in and approval of the plans for the Fossil Cycad National Monument development, as having international meaning and significance.

## PHYSICS

**Committee on Coordination of Cosmic-Ray Investigations.** *Progress report for the period July 1935 to June 1936.* (For previous reports see Year Books Nos. 32-34.)

The work of the special Committee on Coordination of Cosmic-Ray Investigations was done through correspondence during the year and at a meeting in Washington in December 1935. Members of the Committee conferred as opportunity permitted with Doctors A. H. Compton, T. H. Johnson, R. A. Millikan, research associates of the Institution, and with others interested in this field.

During the year, under the auspices of the Institution's Department of Terrestrial Magnetism and with the cooperation of the United States Coast and Geodetic Survey, precision cosmic-ray meter No. C-1 was continuously operated at the Cheltenham Magnetic Observatory. At the Huancayo Magnetic Observatory of the Institution's Department of Terrestrial Magnetism, cosmic-ray meter No. C-2 was installed by O. W. Torreson, Observer-in-Charge, in April 1936 upon the completion of the specially constructed frame addition to the anemograph building on the Observatory's site; records have been obtained continuously since May 1936. With the cooperation of the Department of Scientific and Industrial Research of New Zealand and the Director of the Christchurch Observatory, and upon completion in June 1936 of a special frame building at the Amberley branch of that Observatory, meter No. C-5 was installed by Professor P. W. Burbidge of Auckland University College, and S. W. Beagley, Computer of the Christchurch Observatory; continuous recording was begun in June 1936. Cooperating with the Institution's Department of Terrestrial Magnetism, Professor J. Gallo, Director of the National Astronomical Observatory of Mexico, arranged for and completed in May 1936 the construction of a specially well-insulated frame building adjoining the site of the Magnetic Observatory of that organization at Tacubaya, Mexico; after some instrumental improvements a meter will be installed there, it is hoped, by December 1936.

To facilitate installation and operation of the meters, and after a period of recording at Cheltenham, the Department of Terrestrial Magnetism completed, in cooperation with Dr. R. L. Doan and Dr. A. H. Compton, a 36-page illustrated circular of "Instructions for installation and operation of Model C cosmic-ray meters."

Analysis by S. E. Forbush of the Department of Terrestrial Magnetism of the data obtained at Cheltenham, through the application of statistical methods, already has served to clarify some of the previously existing uncertainties regarding the effect of changes in barometric pressure upon the observed cosmic-ray intensity. It has been found that the reliability of barometric coefficients derived from a given series of data has heretofore been greatly overestimated. As a result, many of the differences in the barometric coefficients which have previously been regarded as real now appear to be statistical. A sufficiently reliable barometric coefficient has been obtained from the Cheltenham data to warrant an investigation of the diurnal varia-

tion. Such a study, using the technique developed by Dr. Bartels, has already been completed for nearly 200 days. Besides providing the necessary material for determining the reality of the diurnal variation (and this has not been done heretofore), this analysis has provided the means for testing whether the observed diurnal-variation has been distorted because of small variations in the temperature of the apparatus. It will also make possible a test to determine whether air-temperature has any effect (such as has been reported) upon the observed cosmic-ray intensity. At present, the analysis indicates no definite justification for applying such a correction for air-temperature. On this basis, the analysis of 200 days of data from the Cheltenham meter yields, when corrected for atmospheric pressure, a diurnal variation which is statistically real. The amplitude of the 24-hour wave is about 0.2 per cent of the total cosmic-ray intensity and its maximum occurs about noon. The analysis for 100 additional days is nearly completed.

Excellent progress was made during the year by Doctors Compton, Johnson, and Millikan, and their associates, as indicated in the three attached reports. Valuable suggestions for continued cosmic-ray research were submitted individually by them for the calendar year 1936. Because of the limited funds available and following its adopted policy to eliminate duplication, the Committee recommended consideration of a limited number only of the suggestions. These recommendations were approved by President Merriam for the apportionment of funds in 1936 as follows: (1) Continuance of program for precision cosmic-ray-meter installations; (2) continuance of program of high-altitude research to include observations on mountains and by balloons and special radio recording devices; (3) development of cosmic-ray counter-telescope; (4) comparison of cosmic-ray depth-ionization curves at depths to 1000 feet; (5) full- and part-time services of assistants for work being done by Dr. Millikan and for analysis of data obtained from precision meters. The unexpended balances from allotments made for items indicated in previous reports have been continued available for the purposes originally named.

The three cosmic-ray electroscope-recorders of the Millikan-Neher type ordered by the Committee from the California Institute of Technology were received in June 1936 after standardization at Pasadena. They are now ready for assignment during the next report-year.

The staff of the Department of Terrestrial Magnetism, as a result of extensive experience with observatory apparatus for continuous registrations and study of the records obtained at Cheltenham, made suggestions to improve the precision cosmic-ray meters of type C. Among the more important items were:

(a) Experimental establishment by thorough analysis of meters operated side by side for a statistically adequate period to obtain a measure of the real absolute accuracy with which separate cosmic-ray meters may be relied upon. This involves particularly the barometric correction for individual meters, the absolute value for cosmic-ray ionization, and residual differences between average results.

(b) Instrumental improvements to include (1) automatic insulation-test, (2) determinations of temperature coefficients, and (3) improvement of barometric records.

(c) Desirability of operating instruments of different types under the same conditions for similar purposes at one station for statistically adequate period, as data so obtained will be even more convincing and valuable as regards any conclusions on barometric corrections and other fluctuations.

The Committee has arranged with Dr. B. F. J. Schonland that he continue to December 1937 the observations with the Steinke cosmic-ray apparatus at Cape Town; Dr. Schonland is also tabulating and supplying the hourly results obtained with this apparatus from December 1935. Dr. V. F. Hess is also continuing for one year the corresponding work at Innsbruck.

Distinct progress is shown in Dr. Johnson's report on balloon-flights from the summit of Mount Washington, in one of which cosmic-ray intensities at the ground station were received by radio from the balloon up to a height of eleven miles. Since May 6, Dr. Johnson has been assisted by Alexander A. McKenzie, who did such successful radiosonde work in the meteorological investigations at Mount Washington. It is also to be noted that Dr. Millikan reports on successful work by balloon at San Antonio and on flights in South America. The work of Dr. R. D. Bennett of the Massachusetts Institute of Technology is indicated in Dr. Compton's report. Dr. Millikan had completed by the end of June 1936 arrangements for further energy-measurements in Panama in the equatorial belt. Reference may be made also to further observations on board ships traveling north and south, including the Grace Line vessels *Santa Barbara* and *Santa Lucia* on which Dr. Johnson has installed a recording cosmic-ray tube-counter, and on the Canadian-Australian Steamship Company's liner *Aorangi* on which Dr. Compton has installed one of the precision cosmic-ray meters.

In expressing grateful appreciation to all who have cooperated in the Committee's work as mentioned above and others in the attached reports, we wish to record our obligation to the Union Carbide and Carbon Corporation which has so generously provided through Dr. Compton the necessary batteries for the operation of the precision cosmic-ray meters.

W. S. ADAMS,  
JNO. A. FLEMING,  
FRED E. WRIGHT.

**Compton, A. H.,** University of Chicago, Chicago, Illinois. *Studies of cosmic rays.* (For previous reports, see Year Books Nos. 31-34.)

Our work during the past year, as supported by grants through the Carnegie Institution, has been confined to the installation and use of the model C cosmic-ray meters. These seven meters were built at Chicago, under authorization of the Carnegie Institution, during the period July 1, 1933, to July 1, 1935, and have been described in previous reports. They are of relatively high sensitivity and supply a continuous record of changes in cosmic-ray intensity. At present, three of the meters are operating in permanent stations, at Cheltenham, Maryland, at Huancayo, Peru, and at Christchurch (Amberly) New Zealand, giving continuous records of the changes in the cosmic rays. Two others, at Chicago, Illinois, and Cambridge, Massachusetts, are engaged in studying special problems connected with sudden bursts of ionization. One is cruising back and forth on the



Pacific Ocean between Canada and Australia, obtaining a precision-curve of variations with latitude. The remaining instrument is at Chicago awaiting installation in Mexico.

#### GALACTIC ROTATION EFFECT

The most important result of these studies has been the establishment during the past year of an effect which seems to be caused by the rotation of the Milky Way. The probable occurrence of this effect suggested itself while our studies of cosmic-ray variations were being planned, and its investigation constituted one of the projects for which the meters were built. More cosmic rays should strike the front than the back of the earth as it moves rapidly through space. Because of the rotation of the galaxy the earth moves at about 300 km per second toward about R.A. 20° 40", and north declination 47°, as a result of which motion a variation was anticipated with sidereal time of about 0.1 per cent (within a factor of 2) at 45° latitude, and a difference of intensity between 45°N and 45°S latitude of about 0.5 per cent.

Tentative confirmation of this prediction was immediately available from some data obtained by Hess in 1932. During the past year the existence of the predicted sidereal variation has been established by three years of measurements in the Northern Hemisphere reported by W. Illing, and by measurements over an equal period in the Southern Hemisphere reported by Schonland and his collaborators. The latter measurements were made with apparatus purchased by a Carnegie grant and from studies directly coordinated with our program. Both investigators report a maximum intensity at very nearly the predicted sidereal time and within the predicted range of magnitude.

Regarding the predicted north-south difference, the data now being collected by our meter on the Pacific Ocean should eventually give a positive answer. At present the southern end of the journey, Auckland and Sydney, is not far enough from the equator to reach the "polar plateau" of cosmic-ray intensity where it is influenced by the latitude-effect. A "knee" in the latitude-effect curve is, however, observed at geomagnetic latitude 38° S, corresponding to a similar "knee" at 41°N, and at these knees the intensity is about 0.6 per cent greater in the Northern Hemisphere. This affords a provisional confirmation of the predicted difference.

The implications of this galactic rotation effect are far reaching. It confirms the astronomers' recent conclusions regarding the existence, the direction and (roughly) the magnitude of the rotation of the Milky Way. It implies that the origin of the cosmic rays is beyond our galaxy; for it is the motion of our galaxy relative to the source of the rays that presumably causes the effect. Since the magnitude of the sidereal variation is only about 15 per cent as great as that predicted on the assumption of photons as the primary rays, whereas it agrees satisfactorily with the prediction based upon primary electrons, its observed magnitude implies that most of the primaries are electrical particles. This confirms the conclusion reached in our earlier reports on the basis of our latitude-effect and similar experiments.

## ENERGY-SPECTRUM OF THE PRIMARY COSMIC RAYS

Our precision data obtained by repeated voyages along the Pacific Ocean have given a much improved energy-spectrum of the primary cosmic rays which are responsible for the latitude-effect. We obtained a rough spectrum of this type in 1933 by comparing our cosmic-ray survey data with the calculations of Lemaitre and Vallarta. Adapting a mathematical procedure developed by Zanstra, which is based upon the fact that at each latitude there is a relatively sharp lower limit to the energy of the electrons admitted by the earth's field, we find the spectrum of the rays between energies  $2 \times 10^9$  and  $19 \times 10^9$  electron-volts. The former figure corresponds to the northern limit ( $54^\circ$  geomagnetic) of the ship's course, and the latter the limiting energy for vertical rays at the equator. Between  $2 \times 10^9$  and  $9 \times 10^9$  eV, the abundance distribution is evidently affected by absorption in the earth's atmosphere. Between 9 and  $19 \times 10^9$  eV the spectrum is a continuous one. The data indicate that most of the primary rays consist of electrical particles of energies greater than  $19 \times 10^9$  eV. These conclusions confirm those previously drawn by Clay on the basis of similar but less satisfactory data.

## STUDIES OF BURSTS

R. L. Doan at Chicago, and D. Heyworth and R. D. Bennett at Massachusetts Institute of Technology, have continued their studies of ionization-bursts, using our model C meters. The main result of Dr. Doan's measurements has been to refine the earlier finding that the rate of appearance of bursts increases to a maximum as lead shields of increasing thickness are placed over the ionization-chamber, and then decreases rapidly with the addition of further lead. This decrease in burst-rate is much more rapid than the decrease in ionization produced by the main cosmic-ray beam, which seems to mean that the bursts are not caused by the main body of primary cosmic rays, but rather by a separate component.

The experiments by Dr. Heyworth and Professor Bennett have added the important information that paraffin placed above the chamber has but little effect on burst-production as compared with an equal mass of lead. This corresponds rather closely with the relative effectiveness of these materials in shower-production.

## COSMIC-RAY STATIONS

Though some difficulties have been encountered with the meters at Cheltenham and Christchurch, valuable data are now being collected at both of these stations and at Huancayo. As yet these data have, however, not been reduced to usable form, and longer series of measurements are required. In Mexico the cosmic-ray observatory is now completed and awaits installation of the meter.

## PERSONNEL AND ACKNOWLEDGMENTS

During a part of the year, Dr. R. L. Doan has been employed to take charge of the installation and adjustment of the meters. Mr. S. E. Forbush, of the Carnegie Institution, has supervised the operation of the meter at Cheltenham, and Mr. O. W. Torreson has put the Huancayo meter in opera-

tion. We wish to thank Professor P. W. Burbidge, of Auckland University College, and Mr. J. W. Beagley, of the Magnetic Observatory at Christchurch, for putting the New Zealand meter in operation. Of special value has been the help of First Officer R. N. Turner of the R.M.S. *Aorangi*, and the courtesy of the Canadian Australasian Steamship Company in securing the data on the Pacific Ocean. The work of Professor R. D. Bennett, of Massachusetts Institute of Technology, and Dr. D. Heyworth of Wellesley College, using one of these meters has been described above. We wish to express our continued thanks to the Union Carbide and Carbon Corporation who are giving us the specially constructed Eveready batteries for the operation of the meters.

**Johnson, Thomas H.,** Bartol Research Foundation, Swarthmore, Pennsylvania. *Studies of cosmic rays.* (For previous report see Year Books Nos. 32-34.)

The central problem toward which the various studies carried out by me and under my direction at the Bartol Research Foundation are directed concerns the nature of the primary cosmic radiation, its distribution between electrically charged and electrically neutral radiation, the distribution of the charged component between positives and negatives, the distribution of each component in the energy-spectrum, and the specific nature of the rays in each component. The solution of this problem may constitute the basis for speculation regarding the places and processes of origination of the cosmic radiation. In its solution many subsidiary problems arise, such as those dealing with the processes of absorption of cosmic-ray energy in the atmosphere and in other forms of matter and those having to do with the effect of the earth's magnetic field on the spacial and angular distribution of intensity at the earth's surface. The most direct approach to the problem is the study of the geomagnetic effects which manifest themselves as a variation of the intensity of the radiation with latitude and a variation of the intensity at any one location with the direction of incidence. Because of the latter effect there is an east-west asymmetry of the intensity near the equator and, in intermediate latitudes, besides the east-west asymmetry, there is also a north-south asymmetry. The variation of the intensity from any one direction as a function of the latitude depends upon the total electrically charged component of the primary radiation, whereas the east-west asymmetry is a function of the excess of positive particles over the negatives within specific energy-bands. A study of the two effects together can result in determinations of the intensity due to each sign of charge individually. The specific nature of the particles must be inferred from their absorption in the atmosphere, but because of the geomagnetic effects it is possible to study each of the magnetically resolved components separately.

#### RESULTS OF THE AUTOMATIC UNIDIRECTIONAL COSMIC-RAY RECORDER

For determination of the relative intensities of positives and negatives in the primary cosmic-ray beam, measurements of the asymmetry and latitude-effect must be combined. The former measurements, reported previously,

have been made with coincidence counters, whereas our knowledge of the latitude-effect depends upon electroscopes measurements. It is desirable to have both effects measured by the same technique and the calculations are simplified if the latitude-effect is known for particular directions. Both of these features are realized by an apparatus which has been in operation during the summer of 1935 and again in the summer of 1936. The instrument contains eight separate recorders arranged for automatic operation with photographic recording. It is mounted on the upper deck of a ship and goes unattended on extensive voyages recording the number of cosmic rays which pass through the instrument during each hour of the voyage. Two of the eight recorders receive rays incident from the vertical direction; there are two each for the  $45^\circ$  directions on either side of the meridian; and two recorders are arranged for registration of cosmic-ray showers generated in a block of lead. During the summer of 1935 a successful record was obtained on a voyage from New York,  $41^\circ$  N, to Valparaiso,  $33^\circ$  S, on the Grace Liner *Santa Barbara*. The principal results of that voyage have been confirmed by a second voyage in 1936 on the Grace Liner *Santa Lucia* from New York to Talcahuano,  $36.5^\circ$  S. A variation of the intensity of the vertical radiation of the order of 18 per cent was found compared with the 7 per cent latitude-effect found with the electroscopes technique by Millikan and Neher. The sidewise radiation, indiscriminantly recorded by the electroscopes, must be nearly constant at all latitudes and its presence masks the large latitude-effect characteristic of the rays which experience the minimum of absorption in the atmosphere along the vertical path. The large latitude-effect for the vertical rays is consistent with the absorption-coefficients, found by other means, of the field-sensitive component of the radiation, but, because of the directional resolution of the new instrument, the results bring out certain features of the latitude-effect which will lead to better accuracy in the estimates of the composition of the primary radiation. Among these is an effect of the local irregularities in the earth's field, not included in the field of the eccentric dipole, which consistently appears in the results of the vertical counters and indicates that the vertical intensity correlates with the local horizontal magnetic intensity, whereas the total radiation from all directions correlates with the geomagnetic latitude or, in other terms, with the average magnetic intensity due to the eccentric dipole. This local-field effect can readily be explained by consideration of the nature of the orbits of rays which are incident vertically since these experience most of their bending during the last few thousand miles, whereas rays incident obliquely may spiral close to the earth for much greater distances. In applying the new results to a determination of the relative positive and negative intensities the local-field effect introduces an element of difficulty which is yet to be cleared up theoretically, but it is already clear that the new results are in better accord with the large asymmetries found in the equatorial zone than were the results found by the electroscopes which indicated practically no variation with latitude between  $15^\circ$  S and  $15^\circ$  N magnetic latitudes. Within the limits of present accuracies in the theory, the primary radiation may be almost entirely positive.

Another indication of the absence of negatives in the primary radiation has resulted from the records of the instruments inclined at  $45^\circ$  to the west and to the east of the meridian. A large latitude-effect occurs on the eastern side, corresponding to the positive rays, whereas practically no western latitude-effect was found. The latter is a direct measurement of the negative intensity in the higher energy limits and it is possible to state definitely that these are less than one-third as intense at sea-level as the positives in the same energy-band. This conclusion can now be stated without relying in any way upon the theory of the orbits.

The results of the shower-recording confirmed the less reliable result found previously and reported last year that the shower-producing rays at sea-level were less effected by changes of latitude than the total radiation or the shower-producing radiation at high elevations. This brings out an important distinction between the shower-producing process and the processes by which other cosmic-ray effects occur, although there are two possible interpretations. Either the showers are generated by a distinct component of the primary radiation, which, because of the slight asymmetry in the equatorial zone reported last year, may consist of positive and negative electrons, or the showers are produced with higher frequency by the highest energy rays whose magnetic rigidity is above that which can be effected by the earth's field.

#### FURTHER STUDIES OF THE ASYMMETRY OF COSMIC-RAY SHOWERS

These have consisted of tests on the instruments used in 1934 for the study of the asymmetry of cosmic-ray showers at high elevations in Mexico. In those measurements no asymmetry was found, but there was some question about the directional selectivity of the instruments used. The apparatus has been tested against a vertical rock cliff in a stone-quarry. The difference in the number of showers recorded when the apparatus was pointed into and away from the cliff indicates that the directional selectivity was sufficient to establish the result formerly reported that the showers are not as asymmetric in their distribution as the total cosmic radiation.

#### STUDIES OF THE ASYMMETRY AT LARGE ZENITH-ANGLES

Previous results at several different stations had indicated a slight asymmetry of cosmic rays close to the horizon which could have been ascribed to primary rays deflected close to the earth after being slowed down by atmospheric absorption. An apparatus for measuring this effect with greater precision than that realized previously has been constructed, but the investigation is not yet completed.

#### ABSORPTION OF COSMIC RAYS IN THE EARTH

An apparatus for measuring cosmic rays of very low intensity has been constructed for some tests in deep mines. This apparatus is now under laboratory test and it will be used for studying the absorption of cosmic rays of such energy that they are able to penetrate to great depths.

## RADIO-BALLOON MEASUREMENTS OF COSMIC RAYS IN THE STRATOSPHERE

One of the most important remaining problems in the cosmic-ray investigation concerns the geomagnetic effects of cosmic rays of low penetrating power found only in the stratosphere. Since this study involves measurements at all latitudes, in some of which there are no populous countries, it is necessary to develop the technique of the radio-balloon so that it will not be necessary to recover the cosmic-ray measuring instruments. An apparatus for recording coincidences due to cosmic rays has been developed and some tests have been made on balloons and radio-transmitting apparatus. Two successful flights were made in May and June 1936 with cellophane balloons of 1800 cubic feet capacity. These carried apparatus for transmitting signals to indicate the barometric height. A third flight with similar equipment was made with three small rubber balloons. As a result of these flights we are now in position to proceed with flights carrying apparatus for measuring the cosmic rays as well as for indicating the barometric height. Four such flights are now prepared and it is hoped to have these take place in the early fall of 1936.

In the work of developing the radio-balloons and equipment I have had the cooperation of Mr. A. A. McKenzie, formerly of the Blue Hill Meteorological Observatory, of Dr. D. N. Read and of Dr. Jean F. Piccard. Dr. Read has cooperated in the work with the ship apparatus and the asymmetry measurements and Mr. D. B. Cowie helped with the tests on the shower apparatus.

A report of the results with the ship apparatus has been published in the Transactions of The American Geophysical Union and was presented before the American Physical Society and the Geophysical Union.<sup>1</sup>

**Millikan, Robert A.**, California Institute of Technology, Pasadena, California. *Studies of cosmic rays.* (For previous reports see Year Books Nos. 31-34.)

The specific results that have been obtained during the year from July 1, 1935, to June 30, 1936, in the cosmic-ray researches carried on at the California Institute of Technology with the aid of funds provided by the Carnegie Corporation of New York administered by the Carnegie Institution of Washington, may be briefly summarized as follows:

(1) *New evidence has been obtained that incoming electrons (+ and -), not protons or other heavy charged particles, produce practically all of the atmospheric ionization that is due to incoming charged particles at all.* H. Victor Neher and R. A. Millikan have this year completed their "Precision World Survey of Sea-Level Cosmic-Ray Intensities" begun in 1932, and have established a world chart of equal cosmic-ray intensity lines. This chart was first presented at the meeting of the National Academy of Sciences in November 1935, and at the special request of Director Fleming was incorporated in the Carnegie Institution report issued December 13, 1935. It represented the first such chart ever published. The new evidence for the

<sup>1</sup> Trans. Amer. Geophys. Union, 176, 1936.

foregoing conclusion is found in the fact that this precision survey shows that there is but one magnetic latitude, not two or three, at which, in going southward from the north magnetic pole, a sudden decrease occurs in the intensity of the sea-level cosmic-ray ionization. This single sudden setting-in of "the equatorial dip" in cosmic-ray intensity actually occurs just south of Pasadena. But if there were an appreciable number of incoming protons, in addition to electrons, there would be two such sudden dips, one near Spokane, due to the protons, and one near Pasadena, due to electrons (+ or -). The *single* discontinuity in sea-level cosmic-ray intensities occurring sharply at magnetic latitude  $41^\circ$  enables the resistance of the atmosphere to incoming electrons to be fixed through the Epstein-LaMaitre-Vallarta analysis at about 6 billion electron-volts. *The extreme constancy of the sea-level ionization down to magnetic latitude  $41^\circ$  shows that incoming particles of 6 billion electron-volts of energy have a sharply limited range,* and that the effect of practically all incoming particles of higher energy than 6 billion electron-volts reaches down to sea-level. On the other hand, incoming particles of lower energy than this, while definitely shown to have ranges which produce strong ionizing effects in the *upper* atmosphere, are found to produce no observable ionizing effects, direct or indirect, which reach down to sea-level.

(2) *The break-down at high energies of the Bethe theory of nuclear absorption.* The identity of our altitude ionization-curves up to 22,000 feet between Spokane (magnetic latitude  $54^\circ$ ) and The Pas (magnetic latitude  $63^\circ$  north) shows that the effects of 2.4 billion electron-volts (the energy required at magnetic latitude  $54^\circ$  to get through the blocking effect of the earth's magnetic field) can not reach down to 22,000 feet, though they are abundantly found above this altitude. These definite indications of a *range* in the incoming electrons of less than half an atmosphere for 2.4 billion-volt electrons, and a range of a whole atmosphere for 6 billion volt electrons, show that the Oppenheimer-Bethe-Heitler absorption-law, heretofore proved to hold for low-energy electrons, can not hold for electrons of energies of a few billion electron-volts. For this law requires the absorption produced by a given thickness of matter to be proportional to the energy of the electrons incident upon it, and this means that 6 billion-volt electrons would have practically the same penetrating power as 2.4 billion-volt electrons. That this is not the case is proved by the fact that at Pasadena the effects of incoming 6 billion-volt electrons are felt at sea-level, whereas the constancy of the ionization at an altitude of 22,000 feet between Spokane and The Pas means that the effect of 2.4 billion-volt electrons can not penetrate down to an altitude of 22,000 feet above the earth's surface. In other words, 6 billion-volt electrons actually are found to have more than twice the penetrating power or range of 2.4 billion-volt electrons. This is in violation of the Oppenheimer-Bethe-Heitler law of absorption.

(3) *No difference larger than 5 per cent—this represents about the limits of experimental uncertainty—is found in the cosmic-ray ionization in the Philippines and in Peru at an altitude of 26,000 feet.* Bowen, Millikan, Korff and Neher have this year made studies with the aid of Neher electroscopes sent up in airplanes to altitudes of 29,000 feet in Peru and 26,000 feet in the Philippines. These measurements have shown definitely and unam-

biguously that if there is any difference at all in the cosmic-ray ionization in the atmosphere up to 26,000 feet in Peru and the Philippines, it is not more than 5 per cent, which for the higher altitudes is within the limits of observational uncertainty. These observations have shown also that up to the altitudes reached the ionization, both in Peru and in the Philippines, increases *exponentially* with an absorption-coefficient  $\mu=0.5$  per meter of water and reaches at 29,000 feet a value of about 50 ions, which is approximately half its value at the same altitude here in the neighborhood of Pasadena, where  $\mu=0.55$  per meter of water. These measurements destroy the validity of the chief argument that has been advanced in the past for the view that the cosmic rays that come into the equatorial belt are almost wholly, if not wholly, charged-particle rays, rather than photons. They do not enable us yet to determine the ratio of incoming electrons to incoming photons.

(4) *Shower-phenomena show about one-third as large a latitude-effect as do single rays coming in vertically.* Dr. William H. Pickering has this year, in a trip made from Los Angeles to Sydney and return, measured the latitude-effect of showers and compared it with the latitude-effect obtained with a pair of coincidence counters set in a vertical line. In agreement with T. H. Johnson, who has made similar measurements, Pickering finds that the latitude-effect obtained by an arrangement which measures showers is something like one-third that shown by a device which measures *vertical* coincidences. Indeed, he finds a smaller-latitude-effect with his shower-measuring device than Neher and I have found when we used electroscopes as our indicators. If this result is correct (the measurements are not as yet very precise), it constitutes another indication that the incoming cosmic rays in the equatorial belt are at least partially photons.

(5) *Greatly increased accuracy in the measurement of cosmic-ray intensities has been obtained at altitudes higher than those which have heretofore been reached with electroscopes.* After two years of effort H. V. Neher and S. K. Haynes have completed the design and construction of some new electroscopes to be sent up in sounding-balloons. These electroscopes are in principle like those which Dr. Neher has designed and constructed for use in airplanes, save that instead of charging every four or five minutes by contact with the terminals of a battery, the charging is here done by contact with the terminals of a condenser. This condenser has been so perfected that it loses less than one-half per cent of its charge in three hours. The whole instrument, including electroscope, thermometer, barometer, and driving mechanism weighs but 1200 grams. These instruments increase many fold the precision that can be obtained with electroscopes sent up in sounding-balloons. Millikan and Neher have already sent up these instruments in sounding-balloons from San Antonio, and have obtained exceedingly satisfactory readings up to altitudes higher than those that have ever been obtained in cosmic-ray measurements. The new record carries the barometer reading to 12.9 mm. of mercury which according to Humphrey's<sup>1</sup> summer tables corresponds to 92,000 feet, or more than 28 kilometers.

(6) *Much smaller cosmic-ray ionization found in electroscopes at 92,000 feet than at 64,000 feet.* The foregoing experiments at San Antonio (mag-

<sup>1</sup> Humphreys, *Physics of the Air*, p. 74, 1929 Ed.



netic latitude  $38.5^\circ$ ) reveal that in this latitude the ionization in *electroscopes* rises nearly exponentially (with  $\mu=0.52$  per meter of water) to an altitude of about 64,000 feet and then quite suddenly begins to decrease so that at 92,000 feet it is as much as 20 per cent lower than it was at 64,000 feet. Indeed, these new instruments make possible a precise latitude-study at very high altitudes, studies from which it should be possible to determine quite definitely whether the rays which come into the equatorial belt are primarily photonic in nature or primarily charged particles.

(7) *A new type of nuclear absorption not due to pair formation.* Dr. Anderson and Dr. Neddermeyer in July-August 1935 mounted our huge magnet, designed for measuring the energies of cosmic rays, upon a truck and pulled it to the top of Pikes Peak, where they ran it for a month with the aid of a special power-plant, also pulled to the summit with the aid of a truck. They took 10,000 photographs on the summit. The most significant new result obtained from these cosmic-ray photographs has been the definite proof that electron-pair production is not the sole agency by which cosmic rays are absorbed by the nucleus of an atom. The photographs reveal definite evidence that the nucleus can be *disintegrated* by the impact of cosmic rays, resulting in the ejection of a proton and one or more electrons. Of the 10,000 photographs taken, about 100 show such evidence of nuclear disintegration through the ejection of a heavy particle. Anderson and Millikan had reported this phenomenon in 1931, but this elaborate study of it in August 1935 for the first time puts it beyond all question. No evidence whatever was found for the view that heavy particles coming in from outside reach the level of Pikes Peak.

(8) *Evidence that up to 300 million electron-volts the loss of energy of an electron in traversing lead is proportional to the electron's incident energy.* A second and a most important result of the energy measurements made on Pikes Peak has been the discovery that the loss of energy experienced by electrons going through a sheet of lead seems to be proportional to the incident energy up to an energy of about 300 million electron-volts. In other words, the Oppenheimer theory seems to hold up to an energy of at least 300 million electron-volts.

(9) *An increase of ten-fold in the resolving power of cosmic-ray counters.* Dr. H. Victor Neher has this year devised a new counter-circuit which makes it possible to use very much larger counters than have been used thus far. His device has multiplied about ten-fold the counting rate, and this means that the discrimination or resolving power, which is now obtainable with the counter-technique, is about ten times greater than it was before the advent of Dr. Neher's device. The new counters are now being used for a restudy of the latitude-longitude effect with counters and for attempting to find evidence for absorption of cosmic rays in the Milky Way.

The articles which have appeared this year covering portions of the foregoing advances will be found in the Bibliography of this Year Book.

**Committee on the Study of the Surface Features of the Moon.** *Progress report for the period July 1935 to June 1936.* (For previous reports see Year Books Nos. 26-34.)

The Moon Committee has continued, through two additional lunations, to measure the percentage amounts of plane polarization in moon beams from selected parts of the moon's surface. The observations have now been carried through nine lunations and the changes in polarization with changes in phase are known with a fair degree of accuracy. The measurements have all been made at Mount Wilson Observatory with the aid of the six-inch refracting telescope equipped with a special eyepiece which consists of a tilting plate compensator and a detector composed of a biquartz plate, a tilting plate, a Savart plate, and a Wollaston prism. With this eyepiece differences of one-fifth of one per cent in intensity of plane polarization can be detected and measured visually. If a camera be substituted for the eye, a photographic record of the phenomena can be obtained; photographic plates thus exposed show clearly the effects produced by the presence of one-fifth of one per cent of plane polarization in an incoming beam and corroborate the visual measurements. The detector may be used without the compensator for the detection of small amounts of plane polarization in light from distant nebulae. This method is at least five times as sensitive as the usual photometric methods.

Measurements on a series of terrestrial materials have been continued. The plane polarization in light reflected and scattered by terrestrial materials, such as rocks, in the form of (a) rock specimens, (b) rock chips ground on one side to a flat surface by abrasives of different degrees of fineness, and (c) powders of different degrees of fineness from the same samples, has been measured in order to ascertain the effects produced by different types of surface. In rough, non-polished materials the polarization phenomena are in general due chiefly to the effects of diffraction and scattering and only in small part to reflection. Negative polarization, observed both in moon beams and in light scattered by terrestrial materials is caused by diffraction rather than by reflection. Theoretical treatment of this problem is still outstanding; some work was done on it by Fizeau, Rayleigh, and others, but it is not yet in satisfactory state, partly because of surface effects of the materials under test. To render the mathematical approach to the subject as simple as possible, series of measurements are being made on light from diffraction gratings ruled on glass and from celluloid replicas of speculum metal gratings. The gratings are of different numbers of lines to the inch and are measured at different angles of tilt and for different angles between the incident light and the outgoing beam; also for different angles between the plane of incidence and the grating lines. Knowledge of the factors that enter into the phenomena of scattered light is essential to the interpretation of the phenomena observed in moon beams and of their significance in the identification of lunar surface materials.

Pending the completion of the visual measurements, few measurements have been made with the thermoelement, the photoelectric cell, and the polarization quartz spectrograph methods during the past year.

A simple method has recently been developed for ascertaining, from photographs of the moon, the slopes, shapes, and dimensions of its surface features. The moon is so nearly spherical in shape that, for all local measurements, it may be considered to be a sphere. A photograph of the moon is a projection of its spherical surface on a diametral plane normal to the line of sight. With the aid of an accurate lunar perspective polar projection of the same diameter as that of the lunar image on the photographic plate, it is possible, by superposing the projection on the photograph, to ascertain the angle which the incident sun's rays include with the normal to the moon's surface at any given point. If, for example, an inner slope of a crater is greater than the angle of elevation of the illuminating sun's rays, it will cast a shadow; if the slope angle is less, the surface will be illuminated; when slope angle and angle of elevation are equal, grazing incidence is observed. From a series of photographs taken at different times during a lunation it is possible to observe the changes in character of illumination of any given slope and to ascertain its angle. In 1929 a series of motion pictures was taken of the moon with the 100-inch telescope on films in a motion-picture camera. It is now proposed to take, throughout a lunation, a series of photographs on plates at the Newtonian focus of the 100-inch telescope. The photographs will be taken at intervals of 5 or 10 minutes on plates 6 inches on a side. A special 3-element corrector lens has been designed by Dr. F. E. Ross for use at the Newtonian focus and will greatly improve the quality of image at this focus. This set of photographs covering an entire lunation will afford the basis for a better physiographic study of the moon than has heretofore been possible. During the past year the projection method has been applied to a number of photographs of the moon and its feasibility amply demonstrated. The dimensions of a crater, for example, are read off directly in terms of latitude and longitude angles, which are in turn reduced to linear measures by use of a conversion table. The height of a given crater wall above its floor is determined from the measurements of slope angles and distances in the projection. These are read off on the projection and but little computation is required to obtain the linear distances. In the absence of a topographic map, this method enables the geologist to ascertain the shapes, sizes, and relations of the different lunar features. Preliminary measurements on slope angles prove that the inner slopes of small craters (craterlets) are greater than those of the larger craters and walled plains. The slope angle of the inner wall of some of the smaller craters ranges from  $50^{\circ}$  to  $55^{\circ}$ . To the student of lunar physiography the fact that the data are obtained without lengthy computations will be welcome. The Committee plans to make, with the aid of this projection method, a physiographic survey of the major surface features of the portion of the moon visible to us. The task is a large one and will require several years for its completion.

A new series of projections on lunar photographs on globes coated with photographic emulsion has been made and several satisfactory miniature moons have been obtained. In this project the Research Laboratories of the Eastman Kodak Company have contributed effectively by coating the globes with the emulsion. The difficulty heretofore has been to obtain a uniform coating sufficiently thick to obtain an adequately dense positive.

The miniature moons are important aids to physiographic studies; they are free from the distortion and foreshortening present in a moon photograph. On the miniature moon the dimensions of any given lunar feature can be read off directly with the aid of a linear scale.

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## PHYSIOGRAPHY

**Sykes, Godfrey,** Tucson, Arizona. *Continuation of Study of the Colorado Delta and the Lower Colorado River.* (For previous reports see Year Books Nos. 29, 31, 32, 34.)

In the further prosecution of the investigation of the transitional phases through which the lower Colorado and the Delta are now passing consequent upon the recently established control of the river at the Boulder Dam, field studies and the mechanical analysis of bed-silts were continued during the Autumn and Winter, and a report descriptive of the physical conditions and developments in the region to the end of 1935, and of the results of the analyses of detrital material examined within the period, was submitted at the end of March.

The collection of another series of samples of the bed material from the main river channel between the dam and the delta, the delta distributaries, and the irrigation canals in the delta and Imperial Valley which are most affected by the condition of instability in the river, is now in progress. It is planned to subject this material to the standardized form of mechanical analysis developed for the examination of river-bed samples secured both before and subsequent to the closure of the dam, in order, by comparison, to trace and record any further changes in texture which may be taking place.

In the field studies which have been carried out during the year, attention has been devoted to the changing character of the river-bed between the wasteways of the dam and the dispersal area in the delta, and to changes in channel alignment, and to bar erosion and formation, at certain selected points at which conditions were considered to be typical of those existing along the general course of the river.

These local studies were planned and carried out in order to ascertain whether any uniform process of bed erosion was in progress or whether, as had been suspected, certain observed lowerings of bed-levels, which had been tentatively interpreted as due to general scour, might not more properly be attributed to local readjustments of the channel. The method adopted for inquiry into this point may be briefly described.

Suitable sections of the channel having been selected for observation during periods of approximately uniform discharge, the positions of banks, bars, and shoals were noted and plotted. Thin iron rods were then driven vertically into the river bed at different points at which it was evident that movement of the bed material was in progress. The length of each rod projecting above the river bed was measured and recorded, and the measurements were repeated at intervals during the continuance of the experiment. In several cases the observations were continued for periods of ten days, and changes of bed-level of from 12 to 16 inches, plus or minus, were recorded.

As the processes of degradation and aggradation were in many instances found to be going on simultaneously in different portions of the same channel, the conclusion was reached that no general bed-scour was taking place during the periods of observation.

Unfortunately, it is impracticable to carry on an investigation of river-bed changes along these lines when the discharge is irregular, and a sudden increase in the release from the wasteway of the dam brought the work

temporarily to a close and it has not yet been resumed except for a short period during November, when conditions of closely regulated discharge were again favorable.

Visual observations of channel readjustments and changes have, however, been continued at intervals, and at certain selected points, during the Winter and early Spring. Additional field work has been the collection, in accordance with the general plan adopted during the previous season, of two further series of bed-silt samples from four representative sections of the river between the Boulder Dam and Yuma, and also of several more limited series from the Imperial Valley and Delta canals.

These samples—some seven hundred in all—have been subjected to the uniform method of mechanical analysis used throughout the inquiry, and certain progressive changes have been found thereby to have taken place in the composition of the material forming the river bed, during the period subsequent to the completion and closure of the Dam. The changes have been described and the matter quite fully discussed in the interim report above mentioned, but the main features are outlined in the following precis.

In recording the progress made with the Colorado study during the 1934-35 period, attention was called to the fact that the disintegration of the river-bed by the desilted stream issuing from the wasteways of the Dam was the probable cause of the movement into the main irrigation canals of the Imperial Valley and the Delta, of a great body of psammitic material of remarkable uniform texture, which was the source of much trouble and great expense to the operators of the irrigation systems.

As detrital matter of this character which enters the upper basins of the Colorado system is now wholly arrested by the Boulder Dam and retained in Lake Meade, it is obvious that the deposits in the canals have had their proximate origin in the vast deposit of bed material which underlies the river channel between the Dam and the intakes of the several irrigation systems.

A rather sharply defined dimension has been found to exist in the particles which collectively compose the *débris* transported by the Colorado, below which they remain in suspension at the ordinary current speeds developed in passing down the gentle gradients of the lower valleys, but above which they progress principally as "bottom-load" by rolling, sliding, or saltation.

This dimension is approximately 0.075 mm, and in carrying out the examination of the river-bed material by repeated sampling and analyzing before and subsequent to the closure of the Dam, and of the deposits which have appeared in the canals during the Summer and Autumn of 1935, it has again been adopted as the significant point in the classification. Percentages of particle size above and below it have been computed for each group dealt with. The results, as obtained, are of interest.

In the series of samples taken from widely separated but representative collecting areas before the closure of the Dam, approximately 44.0 per cent of the component particles proved to be greater than the critical dimension, and 56.0 per cent were less.

In a second series, collected from the same areas, but some little time after the river had been placed under control and the free movement of *débris* from the upper basins had ceased, the proportions had changed to

77.0 per cent greater and 23.0 per cent less, indicating that a leaching or selective process had been in operation whereby the finer material had been removed and carried forward in suspension.

A third series, collected again from the same areas during the late Autumn and Winter months, showed that a partial reversion toward the first type had occurred—the relative percentages being 57.0 and 43.0. The river discharge during this third period was maintained quite steadily, the suspended-silt content, as determined daily at the intake of the Imperial Canal system, remained very low and the movement of the psammitic material into the canals had almost ceased. It has, however, reappeared in troublesome quantities during the Spring months of the present year, and has been found, upon the basis of some preliminary analyses, to be of practically the same texture, with 90.0 per cent of its component particles above the critical 0.075-mm dimension and 10.0 per cent below that which invaded the canals a year previously.

While the selective leaching processes brought about by the stream of desilted water released from the Boulder reservoir have doubtless been the fundamental reason for the increase in the percentage of the coarser components of the channel-bed material disclosed by the second series of analyses, the cause of the reversion toward the original type, which the third group of analyses indicates, is more obscure and will, perhaps, be only possible of explanation after the material has been subjected to examination and analysis through one or more further fluctuations in river volume.

The comparatively sudden appearance of the heavy bodies of psammitic material in the canals and delta channels is also a matter of some present uncertainty as regards their separation from the river-bed above and their transference en-masse down stream.

The year covered by this report has proved to be an uneventful one in so far as hydrological and climatic conditions in the lower river and delta were concerned. No noticeable increases in the volume of discharge have occurred as the result of local storms in the lower basin areas, and the release from the Boulder reservoir has been maintained at about 7500 second-feet at Yuma, except during a three-month period in mid-winter, when it was reduced by 50 per cent.

The absence of storm waters or of local rains has had the effect of intensifying, through another year, the process of desiccation which has been so noticeable in the delta since the Summer of 1933, and which is gradually reducing the region to the arid condition of the surrounding deserts.

## PHYSIOLOGY

**Russell G. Oscar**, Ohio State University Phonetics Laboratories, Columbus, Ohio. *Physiological cause of voice quality differences*. (For previous reports see Year Books Nos. 28-33.)

Down to 1928 this investigation had confined itself to an X-ray analysis of the tongue and vocal organ positions in vowel production. And we were then concerned primarily with an attempt to ascertain the facts pertaining to speech. When in that year the American Academy of Teachers of Singing obtained funds from the Carnegie Corporation of New York for the extension of this investigation as a part of the activities of the Carnegie Institution, the scope was expanded as indicated in the above title of the project.

We limited ourselves to a study of physiological causes, as substantial analyses had already been made of the physical resultants manifest in kymographic, phonographic, oscillographic, and other sound track tracings; likewise of analogous cavity-tone manifestations in organ pipes and the like, as a means of simulating human results. And studies were made with mechanical resonators, especially as used to perceive the harmonic components in the complex human vowel and voice quality differences. In all of these it had been the custom to assume the physiological processes which might cause the physical facts noted. From the beginning we proposed to reverse this procedure. That meant that we were to ascertain, with such exactitude as scientific equipment would permit, exactly what the physiological mechanism was doing. That involved, for the most part, photographic processes, and most of them had to be studied by means of X-rays, since they are not directly visible.

At the inception of this project, however, we indicated the ideal procedure as one in which every type of record called for by the process studied could be synchronized and made simultaneously. For the physical and the physiological should be studied together. That we had done for all but the oscillographic, prior to 1929. By 1932 as indicated in the Year Book we had gone further, and by 1933 were able to announce before the Acoustical Society success of limited experiments of that nature made with borrowed apparatus, for our means did not permit purchase of the then excessively expensive units. Last year we were ready to make report on synchronized experiments in which we obtained simultaneously (1) X-ray photographs at 1/120 of a second, showing even the very fleeting vocal organ positions, and hence much superior to motion-picture X-rays; (2) a phonographic record so that one could listen back to exactly what the sound quality was at the instant of exposure; (3) a high quality oscillographic record from which the most exacting physical analyses could be made in order to ascertain what components were present at the instant of exposure; (4) a high-speed external motion-picture of the subject in his relationship to the apparatus, from which the investigator can largely determine the mental and emotional attitude of the former, the accuracy and naturalness of his position, and many other facts in regard to the equipment and subject at the instant of exposure which otherwise might not be noted at the moment; (5) the synchronization accuracy of each of these recorded along with the time line in



varying fractions of a second on a continuous kymografik record. The whole had been refined by the self-operating features<sup>1</sup> in the X-ray exposing set-up reported on page 357 of Year Book No. 32 for 1932-33.

Since these experiments were now far enough advanced to announce success in a method of attack we had all considered the ideal as far back as investigations ran, but which nobody to date had succeeded in attaining, we deemed it advisable to make report before some international body. Dr. Merriam was kind enough to so authorize this. To do so Dr. Russell left in the Spring so early that no report was made in the Year Book for last year. Hence the activities for the two-year period are now included.

Report was made<sup>2</sup> before the International Congress of Phonetic Sciences meeting last summer in London, England, and since published in the proceedings thereof. The International Neurological Congress followed at the same place. Then report was made<sup>3</sup> before the International Physiological Congress meeting in Leningrad, Russia, on the physiological laryngeal processes manifest in the high-speed motion-pictures of the interior larynx in unimpeded human function, which this project was the first and, to date, the only one to obtain. The demonstration aroused such interest among the scientists assembled that it had to be repeated three times at the request of Congress officials. Along with our Carnegie Institution colleague, Dr. Carl G. Hartman (who, be it said in passing, made a profound impression on his colleagues in Russia), we returned by way of Königsberg, Germany, instead of the route through Poland taken by the others, where several weeks were spent pursuing our investigations.

It will be remembered that three of the most famous physiologists to concern themselves with this problem of voice quality have successively followed each other as directors of the Physiological Institute of the University there: Helmholtz, Hermann, and Weiss, the latter still the incumbent, and our teacher of a number of years ago. The Dean of the Medical School, Dr. Berger, became interested in our last-named experiments and called the oto-laryngologists together for a half-day demonstration. This we repeated before the medical groups in Köln, Germany, and Paris, France. These studies on the function of the larynx are being continued and, since the demonstrations of last year, we have completed apparatus which will add materially to the information we hope to be able to publish next year.

Dr. Robert O. L. Curry of Armstrong College, Durham University, England, became interested in the possibilities of synchronized, simultaneous X-ray and oscillographic studies such as above announced. He had been working with Dr. Richardson, chairman of the physics department there, who recently published in the *Musical Courier* another very interesting study bearing on the subject of the human voice. Dr. Curry joined our staff last Autumn, as a Commonwealth fellow. In consequence, the graduate school of Ohio State University, through the interest of Dean McPherson, saw fit to provide us with the expensive oscillographic addition to

<sup>1</sup> G. Oscar Russell, *An Automatic Speech and Voice X-ray Exposure Mechanism*, Carnegie Inst. Wash. Year Book No. 32, p. 357, Dec. 15, 1933.

<sup>2</sup> G. Oscar Russell, *Synchronized X-ray, Oscillographic, Sound, and Motion Picture Studies of Speech and Voice Production*, Proc. Internat. Cong. Phonetic Sciences, London, 1935.

<sup>3</sup> G. Oscar Russell, *New Light on Some Physiological Functions of the Larynx*, Proc. Internat. Physiol. Cong., Leningrad, 1935.

the set-up, of which we spoke above. A cathode-ray ultra high speed unit seemed advisable, and of necessity had to be specially constructed. Unfortunately, it had not been ordered until Dr. Curry arrived, hence the year was well gone before it became available. Interference between the X-ray and this unit has presented some extremely baffling problems which it will take some time to master, thus his entire year has been spent on problems of technique and equipment.

Dr. Jack C. Cotton, another member of our staff, took advantage of this addition to our equipment to carry to oscillographic record conclusion a number of his most productive investigations initiated in 1932. These he has now ready for publication. Some of the most important may be summarized:

(1) He devised a piece of apparatus which made it possible for the experimenter to control the whole buccal passage from the pillars of the fauces to the lips, and force its conformation to a constant, while the subject was intoning any vowel. In other words the subject was left without any power of changing this front mouth passage, though free to change the pharyngeal and vocal adjustment. The resultant sound could then be recorded oscillographically and phonographically. He reports, "our experiments . . . indicate . . . that the pharyngeal cavity variations and possible laryngeal tone quality variations are practically the all-important factors in vowel differentiation, since it is possible to produce any vowel while maintaining the oral cavity configuration which is characteristic of *i* (*ee*, as in *peep*). . . . Besides the oscillogram illustrates the possibility of a radical change in wave-picture without loss of vowel character."

This investigation is revolutionary in two respects; First, it indicates the *singer could keep the whole top flat surface of the tongue in one position yet produce any vowel in the gamut. And by corrolary, he might shift this position to make some other change, such as perhaps voice quality, without changing vowel quality.* This again confirms Russell's conclusion announced as early as 1921 in his "The Vowel Triangle a Fallacy," and repeated<sup>1</sup> in "The Vowel," (1928), and<sup>2</sup> *Speech and Voice* (1931), until his studies called attention to the importance of the throat cavity it had been disregarded, and linguists or philologists, for example, had almost universally assumed that historical phonological change was caused by shift in the front tongue position.

In "The Vowel" Russell reported an experiment somewhat akin to this of Cotton, and called attention to a similar one of Marichelle which had been dismissed with a shrug. Cotton's new technique shows that should not have been so hastily done, and again refutes the old vowel triangle assumption.

Second, he shows a fallacy in another assumption heretofore made, in this case most often by physicists, *viz.* that any radical change in wave picture (shown in oscillographic records, for example) would of necessity represent a substantial change in vowel character. Hence these experiments of his cast a shadow of doubt and suspicion, to say the least, on a large body of conclusions drawn by such investigators during over a century now past.

<sup>1</sup> G. Oscar Russell, *The Vowel*, Ohio State Univ. Press. 1928.

<sup>2</sup> G. Oscar Russell, *Speech and Voice*, Macmillan, New York. 1931.

(2) Others of his most vital experiments deal with the human-sound producing mechanism. For over two and a half centuries a furious argument has been carried on as to how the glottal lips function to produce voice. He throws decidedly new light on the subject.

The question is now generally begged, but it is probably justifiable to say that preference is commonly given to the viewpoint<sup>1</sup> of Ferrein (1741) who is responsible for the misnomer, *vocal cords*, and thought of them functioning as vibrating strings, bowed by the air. It was often said to be "a more convenient working hypothesis, best representing the known physical facts." The reason was probably the necessity felt by such scientists, for a harmonic postulate, and the view of some puff-theory proponents<sup>2</sup> that "the puff is a purely mechanical agent having no acoustical function in itself" serving merely to stimulate the transient natural frequencies of the cavities above it.

Three years ago Dr. Cotton devised a very sensitive new-principle and accurate spirometer, which served admirably to measure air puffs of the nature here involved. The oscillograph now available made it possible for him to round out these studies, by more precise investigation of siren puff tones manometrically controlled. Likewise of the air stream intermittently interrupted by the glottis. He reaches some interesting and almost revolutionary conclusions:

*First*—"A vibrating string" (especially one no longer than the 1 to 2 cm. so-called "vocal cord" involved in creating voice) "produces a very feeble tone unless its vibrations are communicated to a large surface or sounding board . . ." one capable of "really miraculous resonant amplification in order for that tone to reach the loudness level . . . characteristic of the normal human voice." And of course no head provides an amplifying system of anything like that size.

*Second*—The glottal puff release "is not unlike the bursting of a small balloon at each laryngeal impulse. . . A single puff. . . in a loud tone on a (220 cps.) shows a volume of 2.35 cubic centimeters. . . And. . . this sudden" explosion "requires only about 0.002 second."

So we see a puff system requires the postulation of no such tremendous amplifying sound board, as would be necessary for a string system. For such an explosive "laryngeal puff. . . effectively increases both factors which make for the propagation of a large amplitude sound wave." That is (a) the area of the wave front is limited only by the area of the air volume into which the explosion is released; and (b) the great compression behind "the sudden escape of a volume of air, such as we find to be present in these puffs, assures us that the amplitude of the resultant sound wave will be large as it leaves the larynx."

Furthermore he disputes the idea that the puff itself would not have a complex acoustic entity, and points out that "the blatant shrieking quality of the fire-truck siren is a familiar example of a complex sound" created by such a puff-producing mechanism.

<sup>1</sup> Ferrein, *De la formation de la voix de l'homme*. Mem. de l'Acad. des. Sc. de Paris 1741.

<sup>2</sup> E. W. Scripture, *Elements of Experimental Phonetics*, Scribners' Sons, 1904, pp. 88-112; *Studies in Experimental Phonetics*, Carnegie Inst. Wash. Pub. No. 57; *The Nature of Vowel Sounds*, Nature 106, 632-4, 664-6, 1921.

He then submits such puff tones to oscillographic analysis and finds:

(a) Them to be very complex.

(b) There is even "a marked difference between the wave pattern for four puffs . . . produced by four successive holes in spite of our efforts to secure perfect symmetry in the turning of the disc and the boring of the holes . . . so that it could not be caused by any lack of uniformity in successive puffs. . . . This makes us appreciate even more the very fine neuro-muscular coordination in the many muscles involved in voice production."

(c) "The unmodified siren tone contains very prominent high frequency components. . . . If the larynx tone is similar . . . our previous centering of attention upon the resonant characteristics of the oral cavity, in particular, has been considerably at fault, where we have assumed it necessary to postulate a small cavity in the front of the mouth" to account for "the high frequency components found in 'front' vowel oscillographic records." "It may well be that the adjustments of the vocal mechanism are directed more often to the task of subduing these high frequencies in the other vowels."

(d) He finds a "characteristic puff oscillation frequency in open air of about 2800 cps." This is in each individual puff, and hence superimposed upon the pitch created by a series. "Bartholomew<sup>1</sup> of the Peabody Conservatory of Music . . . found in his harmonic analyses of singing voices, that good quality voices show a well-marked concentration of energy in the region of 2800 cps . . . responsible for much of the ringing vibrant quality." This indicates "that the singing voices which give evidence of this quality are being produced with sharp puffs at the glottis." It is also a well-known fact that the human ear is particularly sensitive to sounds in this frequency region, which may account for them being "called brilliant." Dr. Cotton then proceeds to develop an explanation of these puff high frequencies which is most interesting and unique, but too involved and long to abstract here. He agrees with Husson and Tarneaud's conclusions<sup>2</sup> drawn from direct stroboscopic observations of the laryngeal mechanism as puff producing.

Russell has been assisted this year by Murray and Stearns; Curry by Thumm; and Cotton by Jones, George, and Baile.

<sup>1</sup> W. T. Bartholomew, *A Physical Definition of "Good Voice Quality" in the Male Voice*. Jour. Acous. Soc., vol. 6, 25-33, 1934.

<sup>2</sup> Husson and Tarneaud, *Le mecanisme de cordes vocales dans la phonation*. Rev. de Laryngol, vol. 8, Sept.-Oct. 1932.

## POINT LOBOS STUDIES

**Point Lobos, California.** *Values of primitive nature.*

On March 1, 1936, the Point Lobos Advisory Committee of the Save-the-Redwoods League rendered to the California State Park Commission a report with recommendations as to policy of administration of Point Lobos Reserve, three miles south of Carmel, California. This unit in the California State Park System is known to artists, writers, scientists and world-travelers because of its picturesque, rocky headlands, its grove of wind-swept Monterey Cypress, and the story it tells of the eternal interaction of sea and land. The report, with minor modifications, was adopted by the Commission, and its acceptance assures the protection of an area of great landscape beauty, possessing many characteristics of the primitive, with a rich flora and fauna, as well as other natural features of scientific interest.

The grants from the Carnegie Corporation and the Carnegie Institution of Washington made possible the investigations and studies upon which this report was based. The Monterey Cypress (*Cupressus macrocarpa*), most distinctive feature of this area and found here in the sole remaining natural grove, was studied from many viewpoints. A notable accomplishment was an intensive investigation under Dr. Willis W. Wagener of the Bureau of Plant Pathology, U. S. Department of Agriculture, of the Cypress Canker which threatens this species in California and has already attained great headway among planted cypress in many parts of the state. Although examination revealed no infections at Point Lobos, the disease was discovered in planted stock less than two miles from the Reserve. A "protective zone" of approximately ten miles around Point Lobos was established by Dr. Wagener and his assistants, and all cypress within this area examined. Infected trees were destroyed and plans made for future systematic protective measures with the cooperation of the state and county authorities.

The firm of Olmsted Brothers, Landscape Architects, Brookline, Massachusetts, was engaged to study the area and make a master plan for its use and protection. This work has been carried on during the past two years under the personal direction of Mr. Frederick L. Olmsted, who spent several months living on Point Lobos, while his assistant, Mr. George B. Vaughan, resided continuously upon the Reserve, as a representative of the Committee, from July 1934 to October 1936. The resultant Master Plan and the statement interpreting it (including an inventory of esthetic values) are considered by those competent to pass upon such matters as outstanding in this field, and a model for similar studies undertaken elsewhere.

Studies of vertebrate animals, by Dr. J. Grinnell and Dr. J. M. Linsdale, of the Museum of Vertebrate Zoology, University of California, covering four phases of the complete annual cycle, revealed a fauna of unusual richness and variety. The results were embodied in a comprehensive report profusely illustrated, wherein 178 species of vertebrate animals were noted and their significance discussed.

Dr. H. L. Mason, Department of Botany, University of California, submitted a "List of Plants, and Recommendations," after studies covering the annual cycle. This report confirmed the fact that the Reserve is also noteworthy in the variety of its flora. The plant census listed 250 species.

Mr. Edward Lee, of the same department, prepared a map showing the plant distribution of the reserve, with accompanying notes.

A report on "The Geology of Point Lobos" was made by Dr. Ralph W. Chaney, Associate of the Carnegie Institution of Washington and professor of Palaeobotany at the University of California, with the assistance of Mr. R. A. Bramkamp, while the latter and Mr. Carlton Condit prepared a detailed geologic map to accompany the report.

An archæological reconnaissance of the area was made by Mr. Waldo R. Wedel, Department of Anthropology, University of California. "Notes on Marine Invertebrates at Point Lobos" were submitted by Dr. Walter K. Fisher, of the Hopkins Marine Laboratory of Stanford University, Pacific Grove, California, and by Dr. James L. Leitch, Department of Zoology, University of California. The movements of visitors to Point Lobos, and studies of human use of the area, were covered in memoranda by State Park Warden R. A. Wilson, Mr. George B. Vaughan and Dr. James L. Leitch, who served as Nature Guide at the Reserve during the summer of 1935.

Dr. H. A. Spoehr, Chairman, Division of Plant Biology, Carnegie Institution of Washington, drew up an outline of "Scientific Work Necessary for the Preservation of Point Lobos," and Dr. Frederic E. Clements, Associate in Ecological Research, Carnegie Institution of Washington, presented "Memoranda on Ecological Suggestions at Point Lobos." Scientific studies based on these memoranda are projected for the coming year.

Two memoranda on "Preservation of the Primitive at Point Lobos," by Dr. John C. Merriam, President of the Carnegie Institution of Washington, were presented to the Committee.

Other reports considered by the Committee included "Regulation of Tourist Travel in the Cypress Grove of Point Lobos," by Dr. E. P. Meinecke, Chief Pathologist, Bureau of Plant Pathology, U. S. Department of Agriculture; "Notes on the History of Point Lobos," by Aubrey Drury; "A Discussion of the Monterey Cypress," by Dr. Willis L. Jepson, Department of Botany, University of California; and "Record of Rainfall and Temperature," Carmel, California, assembled by Dr. D. T. MacDougal, for a fifteen-year period, from the data kept by the Coastal Laboratory of Carnegie Institution.

The Point Lobos studies, and the plan of administration based upon them, are significant in the development of policy governing the administration of primitive landscapes under public control, in several particulars. There was deliberate effort to obtain all important facts as to primary values, esthetic, scientific, educational. The maximum perpetuation of the outstanding values of the area determined the public uses to which it could be put. The rule was established that all artificial development before being undertaken must justify itself on the basis of making these values available for inspiration and education. Interpretation of the features of the Reserve to the public was provided for, because of educational importance and as

an effective means of protection. And, finally, it was recognized that constantly changing conditions in an area like Point Lobos require continued study of trends in growth, in use, and in destructive factors, in order that policy in management may be based on knowledge.

POINT LOBOS ADVISORY COMMITTEE.—Dr. Ray Lyman Wilbur, *Chairman*; Dr. John C. Merriam, *ex-officio*; Mr. Newton B. Drury, *Secretary*.

LANDSCAPE SUB-COMMITTEE.—Mr. Duncan McDuffie, *Chairman*; Mr. Paul Dougherty, Mr. Allen Griffin, Mrs. Robert Hunter, Mr. Carmel Martin.

SCIENTIFIC SUB-COMMITTEE.—Dr. H. A. Spoehr, *Chairman*; Dr. Douglas H. Campbell, Dr. Ralph W. Chaney, Dr. Willis L. Jepson.

## PSYCHOLOGY

**Ruger, Henry A.**, Teachers College, Columbia University, New York, N. Y.  
*Studies on the theory of surfaces.* (For previous reports see Year Books  
Nos. 27, 29-34.)

These studies have been continued with funds made available by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

During the year just passed checking of the values of the higher moments and product moments for the total population of 7000 males has been continued by means of a second series of equations.

The layout for the computation of similar moments for the 28 pairs of traits and for each of the age-groups from 16 to 30 years has been prepared, and the transformation equations have been set up. Some of the moments have been computed and the shifting to the true means of these moments has been begun.

An average force of about seven statistical and research workers under the supervision of Antonia von Brand has been furnished by the Works Progress Administration.



# SEISMOLOGY

## REPORT OF THE ADVISORY COMMITTEE

(For previous Reports see Year Books Nos. 20-34)

### COLLABORATION WITH THE U. S. COAST AND GEODETIC SURVEY<sup>1</sup>

During the past year the Coast and Geodetic Survey has done a certain amount of geodetic work for the immediate purpose of seismological investigations in California. In July of 1935 a leveling party completed the determination of the elevations of many closely spaced bench marks along several short profiles approximately at right angles to faults in southern California. This work was started during the spring of that year. There are eight lines of levels running across fault zones in Kern, Los Angeles, Orange, Riverside and San Bernardino Counties. The bench marks are spaced at intervals of 100 feet within one mile on each side of the fault, 200 feet between one and two miles, 300 feet between two and three miles, 400 feet between three and four miles, and 500 feet between four and five miles. These lines of levels are shown on the accompanying sketch (fig. 1).

It is anticipated that at some time in the not distant future the geographic position of each of these bench marks will be determined. By repeating the field observations for the determination of elevations and geographic positions, the extent to which the ground moves vertically and horizontally during an earthquake can be determined with accuracy.

The desirability of making seismological studies of the region around Helena, where several earthquakes have occurred in the past few years, led to the allotment of Public Works Administration funds to the Coast and Geodetic Survey for making certain field investigations. Of this amount \$3500 was made available for determining several old lines of levels which radiate from Helena and for several hundred miles of additional leveling. This work was started in April 1936 and is in progress at the time this report is being written.

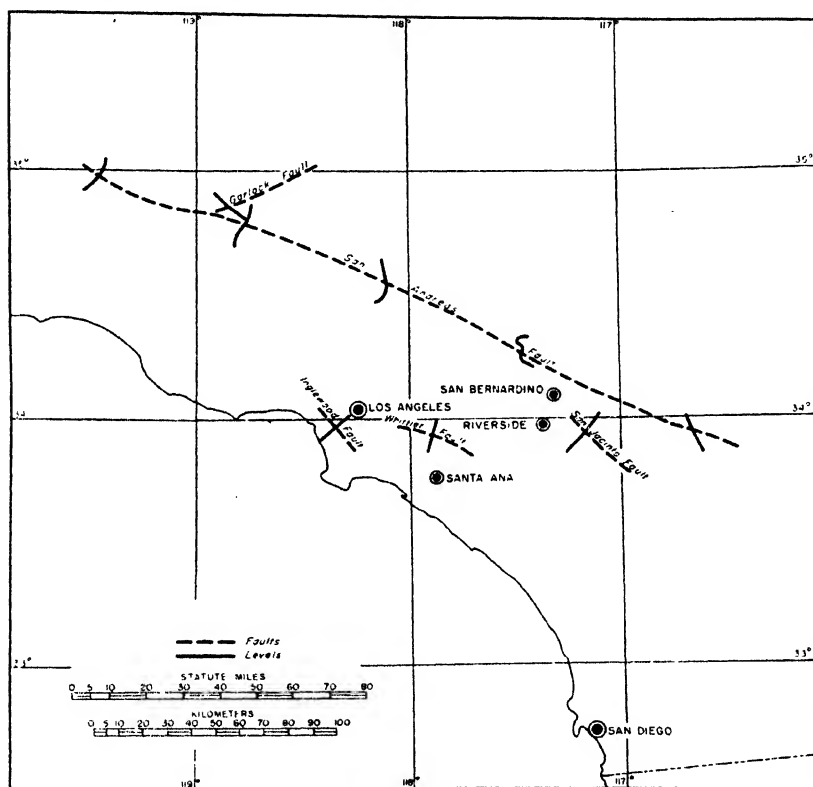
The extensive program of geodetic surveys consisting of triangulation and leveling, which was in progress a year ago, was discontinued early in August 1935, because of the exhaustion of the Public Works funds with which it was carried on, and because additional funds were not forthcoming.

At present there are approximately 67,000 miles of first- and second-order triangulation in the national horizontal-control survey net and 261,000 miles of first- and second-order leveling in the national leveling net. There is quite a large amount of computing and adjusting of field observations remaining to be done for many of the arcs and lines in order to obtain accurate geographic positions and elevations of the triangulation stations and the leveling bench marks, respectively. It is expected that funds will be made available in the not distant future for those computations and adjustments. Even without these adjustments, approximate positions and elevations that will be valuable in connection with the determination of earth

<sup>1</sup> From information furnished by Major William Bowie, Chief of the Division of Geodesy of the U. S. Coast & Geodetic Survey.

movements that may occur near any of the arcs of triangulation and lines of levels are available from the field computations.

The regular appropriation made to the Coast and Geodetic Survey for its geodetic work, which includes an item for geodetic surveys in regions of seismic activity, is less than 30 per cent of what it was a few years ago. With so small an appropriation, it will probably not be possible to provide



the usual allotment for geodetic work in regions of seismic activity during the coming year. The authorization by Congress to the Coast and Geodetic Survey to devote a portion of its funds to geodetic work in regions of earthquake activity began in 1922, with an allotment of \$15,000. That amount was also made available for the next year, but the following year it was reduced to \$12,000 for one year, after which it was further reduced to \$10,000. Approximately \$10,000 has been devoted to this work during each of the past ten years. It is hoped that the normal allotment to the Coast and Geodetic Survey for geodetic work may presently be restored in order that there may be no curtailment of the amount customarily devoted to such work in regions of seismic activity which is of so great importance to seismologists and to all who live in regions exposed to earthquake disturbance.

THE SEISMOLOGICAL LABORATORY<sup>1</sup>

The regular work of the program has continued very satisfactorily during the interval under report—with the interpretation and measurement of the seismograms<sup>2</sup> of earthquakes, distant in origin as well as local, as these shocks have occurred, and research of more general nature as usual. Further work of much importance in laboratory experimentation and the improvement and development of seismic instruments and auxiliary apparatus<sup>3</sup> has been accomplished and is in progress.

The primary purpose of the research program is the sufficiently accurate location of the origins (and the determination of their depth, extent and mode of development) of as many of the local shocks as is possible, or practicable, and the correlation of this knowledge with that of local geological faults, structure and materials, to improve our understanding of the causes and mechanisms of the seismic activity. Involved in this is the recognition and correct interpretation of phases on the seismogram and determination of the corresponding seismic wave-speeds. To accomplish this, accumulating knowledge and experience has made it more and more clear that we must actually make the significant measurements on the seismogram accurate to one-tenth of a second, *i.e.* to  $\frac{1}{10}$  mm. on the record. From the beginning we have striven for this degree of accuracy, but we have not yet quite realized it except under the best conditions. The electrical part of our recording system is now adequate for this, but our gear trains, our time-marking clocks, and the rotational balance of the recording drums, though good, are not perfect. Such sources of error, together with that due to the personal equation, may amount for a given measurement—excluding actual mistakes—at worst to a considerable fraction of a second. At best the accuracy of one-tenth second is attained, but this is not the rule. The average accuracy has not been determined rigorously but appears to approach two-tenths of a second.

Besides these mechanical improvements which must be realized and put into operation to obtain the requisite accuracy in seismometric measurement, additional stations are needed to permit adequate and homogeneous registration, location and depth determination over the whole of the local region which is under investigation. It now happens frequently that small shocks are registered at only one or two of our present stations and that larger shocks occur in places so ill-situated with respect to the present stations that sufficiently accurate location can not be made on the basis of the available instrumental records. Satisfaction of this need must be dependent on the financial resources which can be made available. Until, however, the recording is adequate, mechanically, and the region under investigation is provided with an adequate number of stations suitably located, the routine control of shock occurrence and its correlation with local geological conditions will be incomplete, and perhaps inadequate. For example, in the twelve months, May 1935-April 1936, inclusive, a total of 3901 local dis-

<sup>1</sup> Extracted from the Annual Report of H. O. Wood, Research Associate in Seismology.

<sup>2</sup> Dr. C. F. Richter, R. E. Rogers.

<sup>3</sup> Dr. Hugo Benioff.

turbances have been *recognized* on the records of our seven stations. Of this large number of local shocks it has been practicable to make locations for only 559 independent shocks together with 152 well-located small aftershocks associated with a few of the larger shocks of the group, a total of 711 well-located and approximately located earthquakes. Accordingly with present stations and equipment it has been practicable to locate less than one shock in five of those detected on the seismograms. Small shocks, when not too small, can be correlated with geologic features with less ambiguity than larger shocks with their extended sources. Thus the registration and location of the small shocks is of great importance.

There is still another reason for further improvement of the drum rotation and time-marking to permit more refined measurement. There is suggestion that there are *slight* differences in seismic wave-speeds in different parts of the local region and in different directions within it. It is important to determine whether this is a real condition, and if so how great the differences are. There are geological reasons—differences in nature, thickness and areal extent of different bodies of rock—why there may be such slight variations in seismic wave-speeds. Verification requires still more precise measurement. If the speed differences are significantly large, the accuracy of location is affected.

#### EARTHQUAKE ACTIVITY <sup>1</sup>

The geographical, or better geological, pattern of occurrence of the local shocks varies somewhat from year to year, but it has become plain that there is both (1) clustering of epicenters along known faults (some of which had not yet been discovered when this work was undertaken) and suspected lines and (2) a random distribution of multitudinous small shocks in many parts of the local region. There are also districts which have been free from shock origins during the short interval since registration began in 1927 at three or more stations. Thus far the really considerable shocks which have been well located have all originated along the zones of faulting. If the pattern of occurrence thus indicated is real and characteristic, it is susceptible of reasonable explanation on a geological basis and this explanation can be stated in the form of a hypothesis, the testing of which may well require several years. This hypothesis must be stated elsewhere since adequate presentation will require considerable space.

Some further progress has been made in clearing up arrears of routine measurement for past years. The considerable increase in precision in the seismograms of the last three years renders advisable a thorough revision of previous work, and this can best be carried out when the more recent determinations have been accumulated to a little greater extent.

The circulation of mimeographed bulletins giving data of measurement and interpretation for local shocks, and teleseisms, has continued without interruption or noteworthy delay.

During the twelve months, May 1935 to April 1936, inclusive, local activity was concentrated to a considerable degree in the region to the east and south-

<sup>1</sup> Dr. C. F. Richter, R. E. Rogers.

east from Pasadena as is shown in the following table which gives the total number of shocks of magnitude 3 and higher located within the corresponding rectangles bounded by degrees of latitude and longitude. For example, 18 shocks of these magnitudes were located between  $34^{\circ}$  and  $35^{\circ}$  N. Lat., and  $116^{\circ}$  and  $117^{\circ}$  W. Long.

	122°	121°	120°	119°	118°	117°	116°	115°	W. Long.
38°									
	0	0	0	8	0	0	0		
37°									
	2	2	0	0	3	1	0		
36°									
	1	5	3	14	3	0	0		
35°									
	0	6	8	5	14	18	0		
34°									
	0	0	1	12	19	56	27		
33°									
	0	0	0	1	2	11	38		
32°									
	0	0	0	0	0	9	4		
31°									
N. Lat.									

Pasadena, near the center of the network of stations (X), is situated very close to  $34^{\circ}$  N. Lat.,  $118^{\circ}$  W. Long. The smaller number of shocks in the more remote parts of the table are due to some extent to increasing distances from the stations or to difficulty in making good determinations of location. This is most probably the case along the northeastern margin of the local region. The absence of shocks in the southwestern quadrant, however, represents a real deficiency in activity toward the margin of the continental shelf—a lesser activity than in some former years.

The fourteen shocks in the rectangle  $35^{\circ}$ - $36^{\circ}$ ,  $118^{\circ}$ - $119^{\circ}$ , occurred chiefly in the Kern River region. The most striking concentration of activity was north of  $33^{\circ}$  and west of  $116^{\circ}$ . These shocks occurred chiefly on the active segments of the San Jacinto, Agua Caliente, and Elsinore faults in San Diego County. The numerous shocks immediately to the southeast of these occurred in the Imperial Valley area. The Mojave desert area has continued inactive.

Apparent aftershocks of the Long Beach earthquake are still recorded occasionally. One on December 25, 1935, was felt over most of the area of the Los Angeles Basin and caused some very minor damage at Huntington Beach.

On July 13, 1935, a shock of magnitude 4.5 originated on or near the Foothill fault zone north of Glendora. This shock was felt from Santa Barbara to San Bernardino. No significant damage was reported. The seismograms indicate a depth somewhat larger than usual for our local shocks—say, 20 kilometers.

On September 2, 1935, and on February 23, 1936, there were shocks, probably originating in the San Jacinto fault zone between Riverside, San Ber-

nardino and Colton, which reached magnitude 4.5 and occasioned some minor damage.

The most considerable activity in the Imperial Valley region occurred in September 1935. On September 8, a shock of magnitude 5 originated on the San Andreas fault (or some associated fault) northeast of Holtville. This was felt throughout most of the Valley, and some damage resulted. Shocks from this and other near-by sources continued to occur at rather frequent intervals for some time.

On October 24, 1935, a shock of magnitude 5 originated beneath the San Bernardino Mountains, apparently on the Mill Creek fault. This was felt to distances of about 150 kilometers, but no serious damage was reported. Aftershocks were very numerous.

A shock of magnitude 4.5 originated off the coast of Lower California on October 29, 1935. This was felt at San Diego and as far north as Escondido. This shock is of interest because its source is located on the prolongation to the southeast of the submarine fault line which runs along the northeast coast of San Clemente Island. Shocks at various points along the prolongation of this fault line, both to the southeast and to the northwest, have been recorded not infrequently since the beginning of our program of research. The position of this latest epicenter emphasizes the suggestion that this may prove to be an active fault of no little importance.

A shock on June 3, 1936, was fairly strong in Humboldt County. It is mentioned here because it was well registered at Pasadena and a preliminary estimate gives the magnitude as 5.8. This would make it the largest shock in the California area since that near the head of the Gulf of California on February 23, 1935.

It is of considerable interest to compare the statistics of the larger shocks in our local region during 1935 with those previously given for 1934.

Magnitude	Number of shocks	
	1934	1935
3	114	146
3.5	63	69
4	21	22
4.5	9	10
5	4	4
5.5	1	0
6	1	0
Totals.....	213	251

There is slight but definite evidence of an increase in activity on the basis of shock number, but the total energy released appears decreased. The number of stronger shocks from January 1 to April 30, 1936, has been larger than for the corresponding four months of 1935.

Considerable attention has been given to possible improvement in the location of shocks in the local region *under present operating conditions*. In the routine procedure the largest, best registered or most favorably placed shocks can be assigned epicenters with an error probably not greater than 5 km. in radius. Depths are much less certain—except that the general applicability of the transmission-time data shows that the depths in most instances must be near the generally assumed depth-level of 15 km. This

degree of precision is sufficient for the cataloguing of the shocks of the local region and, in conjunction with the use of the magnitude scale, it yields a listing which affords an essentially true measure of the activity, even though improvement is possible and desirable. When such listing has been continued on the present basis, or with improvement, for a considerable period of years, it should constitute a record of seismic activity within a limited region superior to any previous existing data of the kind, and one which should be of the highest value for statistical study.

Present locations are not yet sufficiently accurate for all geological purposes. Frequently it is impossible to fix an epicenter well enough to distinguish between two or more neighboring faults as the shock source. The limits of accuracy in depth determination are so large as to render discussion of fault dip uncertain. And the well-located shocks are still only a small fraction of all that occur.

The attempt is also being made to bring together the data of groups of shocks having "identical" or very closely adjacent epicenters. With such series of shocks, comparison of the time intervals between the recording of the phases at the several stations will reduce or eliminate accidental errors. Instances are frequent in which these time intervals, as determined in routine, are the same (within one or two tenths of a second) for two or more shocks. Times thus verified afford a more substantial basis for reasoning than the times derived from single shocks. With their aid we may proceed to determine epicenter and depth within definitely assignable limits, and to the investigation of inhomogeneities in structure and variations in seismic velocities such as appear to exist in the local region. For preliminary purposes such work of collation is being confined to the shocks of 1934, and later, since the older data were derived from records less satisfactory from the point of view of instrumental performance. It may later become possible to take up again the records of these earlier years and reinterpret them in the light of the more refined results obtained from the later records.

Six hundred and seventy-six teleseisms were listed in our Bulletin for the eleven months May 1935 to March 1936, inclusive. Of these, three were great earthquakes—that of May 30, 1935, in Baluchistan; that of September 20, 1935, in New Guinea; and that of December 28, 1935, off the coast of Sumatra. A Mexican shock on June 29, 1935, wrote a large record at Pasadena; and the month of September was one of great activity, including the New Guinea shock just mentioned (with two very large aftershocks), a strong shock off north Japan, another in the region of Easter Island, and numerous smaller disturbances. An unusually large number of teleseisms—102—were recorded in December. In contrast, the activity during 1936 down to April 30 has been relatively low, with no very large shocks and no unusual number of smaller ones.

Very large deep-focus teleseisms were recorded on June 24 and July 29, 1935, in the South Pacific, and on December 14, 1935, in South America. The latter is interesting because of a strong aftershock two days later.

The Montana shocks of October call for special comment, as their sequence has a bearing on our local problem. Three important shocks took place on October 11, 18, and 31, 1935 (local dates). The first of these was comparatively small and was definitely registered with small amplitude at Pasadena.

(The fact that considerable damage resulted in Helena pointed immediately to an epicenter very close to that city.) This was followed by numerous small aftershocks, which were still occurring when the larger shock of October 18 took place; this occasioned much damage in Helena and some loss of life. After another interval with many small aftershocks, there followed the shock of October 31; the Pasadena seismograms of this are almost exact duplicates, in amplitude as well as phase intervals, of those of the shock on October 18. There was much further damage, and two lives were lost. These shocks illustrate the danger in making the assumption that once a damaging shock has occurred it will be followed only by small aftershocks, so that the principal risk is definitely over. It is true that in general in the California region the first hard shock has *usually* been the largest; but there have all along been numerous exceptions to this, particularly in the Imperial Valley region. The Parkfield shock of June 1934, with its large aftershocks, is also an exception.

The Canadian shock of November 1, 1935, which was felt over a wide area extending far into the United States, wrote a peculiar and puzzling seismogram at Pasadena; the small and not very sharp beginning is followed by continuous small motion for nearly six minutes, after which the surface waves begin. No definite phases are recorded.

The general study of seismic waves, commenced by Gutenberg and Richter on the seismograms of three large shocks in 1931 and supplemented by data from other shocks, has been rounded off for the present by the publication of a third paper. The first of these papers gave results on travel times; the second dealt with amplitudes, periods and velocities of seismic waves within the earth; the third is a study of surface waves. The whole group of data makes possible a complete revision of the results obtained by seismic methods concerning the structure of the earth, both interior and crustal.

In studying the recorded amplitudes of surface waves it was found that these decrease rather regularly with distance; so that, with some added uncertainty, it has been found possible to extend the magnitude scale, previously set up only for the local area, to shocks occurring in all parts of the earth. In case of peculiarity in the California shocks, either in depth or mechanism of origin, there is some possibility of systematic error in the procedure; but the nature of the conclusions indicates that such errors are not likely to be large. Magnitudes for large shocks can be assigned to half a unit of the scale.

The reported amplitudes for large shocks since 1904 have been examined. The following are some of the conclusions:

The very largest shocks appear to be of approximate magnitude 8.5. These shocks are clearly extraordinary; they occasion earth motion with true amplitude as large as a millimeter even in most distant parts of the globe. Only four of these can be listed, as follows: January 31, 1906, in Colombia and Ecuador; January 3, 1911, in Turkestan; December 16, 1920, China; and November 11, 1922, Chile.

A list has been prepared which includes all the larger shocks during the interval investigated, being those assigned magnitude 8 or over, together with those which are determined as slightly smaller, but which on account



of incomplete or uncertain data, may actually be as large as the others. Fifty-four such shocks are listed. Three occurred in 1935: that of May 30, in Baluchistan; September 20, New Guinea; December 28, off Sumatra. All three are assigned magnitude 7.7 or 7.8.

The San Francisco earthquake of 1906 is assigned magnitude  $8\frac{1}{4}$ ; the Nevada shock of 1915,  $7\frac{3}{4}$  with some question. No other shocks in the California region since 1904 were large enough to be included.

A more detailed listing has been made for the years 1926 to 1930 inclusive, in which an attempt to determine all magnitudes likely to be 7 or over has been made. This list includes 49 shocks.

Both listings are dependable only for shocks of normal focal depth, as the assignment of magnitude has been made to depend on the amplitude of surface waves. Judging by the recorded amplitudes of P, S, etc., deep-focus shocks of large energy are not infrequent; but, especially previous to 1931, published bulletins are so inadequate for these shocks that magnitude assignments are nearly impossible.

Both listings show a proportion of about two shocks in the northern hemisphere to one in the southern. Similar results have been obtained hitherto, but have often been questioned because of the smaller number of stations in the southern region. In the lists here used such a cause of error is excluded; a shock of magnitude 7 occurring anywhere in the world is so well recorded at all stations that it could hardly be overlooked.

The following paragraphs constitute a report<sup>1</sup> on the instrumental work accomplished during the interval under report.

Improvements in the design of the vertical component electromagnetic seismograph have included raising of the transducer structure so that it can be easily removed from the instrument for repair or inspection. Laminated fabric bakelite has been substituted for metal in most of the transducer parts in order to reduce eddy currents produced by leakage flux.

For the determination of constants, a mechanism has been devised for quickly lifting a small test weight from the pendulum. It is operated at a distance by means of a thread which releases a catch on a small spring-lifting device. For routine practise the test weight has a mass  $1/1,000,000$  of the pendulum mass.

Plate glass panels have been built into the framework of the seismometer. These prevent the mechanical action of air currents on the pendulum. It was found that without these panels, the long period galvanometer combination showed large irregular movements.

Experiments on a new core material for the transducer are now in progress. This material is known as 3.8 to 78.5 chrome permalloy. It is expected that with this permalloy the volume of the transducer can be reduced to approximately  $1/6$  of its former value. Furthermore, the permalloy should exhibit much smaller hysteresis characteristics than silicon steel which it replaces.

The galvanometer period in the long period combination has been increased to 80 sec. This has provided a considerable increase in the period range of the seismograph without increasing the response to microseisms of 6-8

<sup>1</sup> Dr. Hugo Benioff.

period. For maximum efficiency the internal resistance of the galvanometer has been made equal to the coil resistance of the transducer. Furthermore, the critical damping resistance of the galvanometer is also adjusted to this same value (500 ohms). Under these conditions it has been possible to introduce a standard 500 ohm T-Pad attenuator between the transducer and galvanometer for the control of sensitivity. Thus changes in sensitivity can be made without disturbing the damping adjustment of either the galvanometer or the seismometer.

In the short period combinations the galvanometer period has been increased to  $\frac{1}{2}$  second. With this value, the galvanometer is operated with critical damping rather than with over-damping. The T-Pad attenuator control of sensitivity can not be used with this combination because of the high motional impedance of the galvanometer at the pendulum frequency.

In cooperation with the California Institute of Technology and the Geophysical Engineering Corporation a new 12-element reflection seismograph has been designed. The seismometers (or geophones) represent modifications of the standard electromagnetic vertical seismometer. The pendulum period is  $\frac{1}{50}$  second. Electromagnetic damping is provided by the reaction of the output currents. The inertia reactor is formed by the moving parts of the transducer. The reactor is supported by four parallel flat springs. An output network in the form of a band-pass filter is provided for each geophone. The transducer inductance forms one of the elements of the filter. The filter serves two purposes: First, it effectively reduces the low frequency or ground roll response, and second, it reduces the phase angle of the transducer currents relative to the transducer velocity. The transducer output impedance is 500 ohms. The amplifiers are of the push-pull type with one stage of resistance-capacity coupling and one stage of impedance coupling. A single anode battery of 90 volts serves for the twelve amplifiers. The galvanometer period is  $\frac{1}{100}$  second. Timing is provided by a 1000-cycle tuning fork and synchronous motor.

A 1000-cycle tuning-fork has been built for use as an earthquake resistant time-piece. The fork is made of cold rolled steel and is driven electrostatically by means of a four-stage amplifier. Since in an electrostatic system of this type the driving force would normally lag the fork velocity by 90 electrical degrees, it was necessary to provide a phasing circuit to reduce the lag to zero. This was made up of a resistance-capacity network similar to the ones used in the quarter-phase driving system described previously. The output from the fork amplifier drives a commercial type 1000-cycle, synchronous clock. The fork temperature is maintained constant within  $\frac{1}{100}$  degree centigrade. The precision of the clock is better than  $\pm 0.1$  second per day. Since the temperature coefficient of frequency is  $\frac{1}{10,000}$  approximately per degree centigrade, it is clear that the variations in clock rate are due chiefly to temperature variations of the fork. It is hoped that a crystalline-quartz unit with a low temperature coefficient can be later substituted for the steel fork.

A paper on Recent Improvements in Electromagnetic Pendulum Seismographs was read before the meeting of the Seismological Society of America in April of this year.

The routine inspection and adjustment of the instruments<sup>1</sup> at the Pasadena and outlying stations have been so effected that troubles occasioning stoppages and loss of records have been reduced to the lowest point since the present apparatus was installed.

Inspection and service trips to the auxiliary stations now average six visits per station per year. This is about half the number necessary five years ago. It also should be taken into consideration that the installations are now much more complex than they were at that time.

The portable station has been maintained in operating condition ready for an emergency. Its gravity-drive clock has always given some trouble and occasionally stopped even when the driving weight was as much as 128 pounds. A sapphire thrust bearing has now been made and installed under the governor spindle. The clock now runs smoothly with 48 pounds of driving weight.

All clocks in the system that have required such attention have been cleaned, oiled and regulated in our laboratory.

A thorough investigation has been undertaken of the irregularities of rotation of two of our recording drums. One was driven by a 10-cycle reed and quarter-phase motor as employed in our auxiliary stations. The other was one of the 60-cycle motor-driven drums in use at the Seismological Laboratory. Second marks were taken optically from a Riefler clock and were recorded photographically on the drums tested. The marks thus recorded were then measured for one revolution of the drum by means of a comparator microscope. Three tests were made on each drum. One with no brake to remove backlash, one with a friction brake, and one with a few ounces of shot in the drum to act as a gravity brake. Further work of this kind is still in progress.

The Riefler clock available for this test was the property of the Mount Wilson Observatory. It had just been overhauled and regulated at the request of the Observatory. Its correction as observed three times per day changed only 0.1 second in three weeks.

A new radio recorder has been designed and constructed in which the beam of light is deflected by two separate prisms. The prisms are each actuated by a telephone receiver unit. One telephone receiver is connected to the radio set, the other to the clock time mark. This recorder is superior to previous ones because of its permanency of adjustment and because the lamp is operated at such a low temperature that it should last almost indefinitely. Since its installation several months ago in Pasadena it has been operating very satisfactorily and it is desirable that similar apparatus be installed at the auxiliary stations.

During the year a considerable amount of experimental work has been done in determining and reducing the effects of air currents and thermo-electric currents on the electromagnetic long period seismograph. Tests on the new instruments for the U. S. Coast and Geodetic Survey, Weston College and others furnished a favorable opportunity for this.

<sup>1</sup> W. W. Miller.

## PUBLICATIONS

The following papers have been published by members of the staff of the Seismological Laboratory during the interval under report.

1. On Seismic Waves (Second Paper), by B. Gutenberg and C. F. Richter. *Gerlands Beitr. z. Geoph.*, vol. 45, 280-360, 1935.
2. On Seismic Waves (Third Paper), by B. Gutenberg and C. F. Richter. *Gerlands Beitr. z. Geoph.*, vol. 47, 73-131, 1936.
3. Revised and Additional Geocentric Coordinates of Seismological Stations, by B. Gutenberg and C. F. Richter. *Gerlands Beitr. z. Geoph.*, vol. 46, 198-201, 1935.
4. Earthquake Prediction, by Harry O. Wood and B. Gutenberg. *Science*, vol. 82, No. 2123, 219-220, Sept. 6, 1935.
5. Magnitude and Energy of Earthquakes, by B. Gutenberg and C. F. Richter. *Science*, vol. 83, No. 2147, 183-185, Feb. 21, 1936.
6. A Linear Strain Seismograph, by Hugo Benioff. *Bull. Seis. Soc. Amer.*, vol. 25, No. 4, 283-309, October 1935.

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*Advisory Committee in Seismology.*

# OFFICE OF PUBLICATIONS<sup>1</sup>

FRANK F. BUNKER, EDITOR

Full recognition of the responsibility of Carnegie Institution for interpreting itself and its work to the general public has come only during the last dozen years; and only during the last ten or twelve years has planned provision been made to meet this responsibility.

## EARLY INTERPRETATIVE EFFORTS

In the early years discussion arose among the Trustees as to advisability of preparing popular accounts of the work for publication. Because of diversity of opinion no effort to inform the public about the Institution was made until 1909, when the Administration Building in Washington was first occupied.

Upon the occasion of the formal dedication of the building (December 13, 1909) the Trustees and their guests assembled in the lecture room of the building where brief addresses were made by the Chairman and Vice-Chairman of the Board and by the Founder. Following these ceremonies a lecture on the work of the Solar Observatory of the Institution was given by Dr. George E. Hale, Director. The company then viewed a number of exhibits illustrating results of work accomplished.

During the afternoons of the week beginning December 13, 1909, the Administration Building was thrown open and between 3000 and 4000 visitors inspected it and the exhibits. As an aid to the dissemination of information about the Institution and its activities, an illustrated pamphlet of 32 pages was prepared and distributed. This was the first time the Institution attempted to acquaint the people generally with the purposes of its work and the results.

In commenting upon the matter President Woodward said a year later:

"In proportion as the work of the Institution is novel, advanced, or fundamental it will be difficult to understand and slow to receive popular appreciation. Some of it, indeed, must be expected to meet initially with disapproval because misunderstood. Hence, to counteract false impressions, to keep the investigator in touch with his contemporaries in other occupations, and to maintain an intelligent public interest in the work of the Institution, it seems essential to hold exhibitions, at intervals of three to five years, similar to that which proved so instructive a year ago."

Exhibits representing work of the departments were again shown on the tenth anniversary (in 1911) of the founding of the Institution. So, also, in 1914, a third exhibition was held and a 20-page descriptive catalogue of the exhibits published. Thereafter, except for the year 1918, annual exhibitions were held but, until 1924, they were largely pictorial and diagrammatic in character with the Office of Administration assuming responsibility for the assembling of materials.

<sup>1</sup> Address: Carnegie Institution of Washington, Washington, D. C.

In 1924 President Merriam appointed an Exhibits Committee, Fred. E. Wright, Chairman, and commissioned it to canvass the situation in the Institution in respect to the selection of materials which might appropriately be used for exhibit purposes.

Meanwhile, the annual lecture by a department head, given before the Trustees and their guests on the occasion of the annual meeting, was, in 1921, replaced by a group of lectures, offered in the fall and spring, to which the public was invited.

Intensive study of the question of interpretation of the investigations conducted by members of the Institution staff of specialists and to development of ways of making the meaning and important implications of the researches widely available began about 1924. Out of the period of discussion, trial, and demonstration that has since elapsed, three important agencies have emerged which have proved their worth: the annual exhibition, the issuance of non-technical interpretative statements for use of the journalistic world and of the schools, and the general and special lectures series.

### THE ANNUAL EXHIBITION

The appointment of the first Exhibits Committee in 1924, as already mentioned, indicated that preliminary study of the problem had brought conviction of the value of the exhibition as an interpretative agency. Yearly, since that time, an exhibition has been held in the Administration Building at Washington, upon the convening of the annual meeting of the Board of Trustees (in December) and for three days thereafter it is open for public examination and study. It is designed to acquaint Trustees and visitors with some of the current investigations, with the methods and apparatus employed in conducting researches, and with the conclusions reached.

Responsibility for organization of the exhibitions rests with a committee of staff members appointed from year to year by the President of the Institution. This committee, in cooperation with department heads, develops a program of research projects in which current progress can be explained to advantage through exhibits. The investigators most closely identified with the selected projects are commissioned to prepare the exhibits, to supervise their installation, and to stand by during the period of the exhibition to tell visitors about the researches upon which they are engaged and to answer questions.

The exhibition committee also provides a program of twenty-minute lectures, given by the exhibitors, which is offered in the lecture hall at suitable times during the periods when the exhibition is open to public view. For the most part, the talks are illustrated with lantern slides or motion pictures and are designed to provide a fuller interpretative explanation of the exhibits than can be given in the exhibit rooms.

So valuable have these simple, clear accounts of the progress of current investigations become, that those of 1935 were published in *The Scientific Monthly* and a pamphlet reprint of the group issued by the Institution in its *Supplementary Publications Series*. Doubtless subsequent lectures, prepared for the same purpose, will be made similarly available.

Well in advance of the exhibition date, the committee, with the help of the exhibitors, prepares the copy for a pamphlet comprising considered statements describing the various exhibits and giving the background information necessary to the understanding of the exhibits and of the research problems that they are intended to elucidate. This pamphlet is widely distributed both before and during the exhibition and, apart from serving as a handbook for those viewing the exhibits, it provides journalists with statements that they find useful in the preparation of articles for the magazines and newspapers which they represent.

### ISSUANCE OF NON-TECHNICAL INTERPRETATIVE STATEMENTS

A second activity relating to interpretation of the work of the Institution that has been developed during the last ten years comprises the preparation of material for use by newspapers, by the weekly and monthly journals that minister to the needs of the general reader, and by schools.

When, for example, a striking discovery has been made or some particularly significant step has been taken in research procedure, a brief statement covering the matter, prepared in cooperation with the investigator most concerned, is presented in mimeographed form to the principal nation-wide news distributing agencies for immediate release. If the statement is judged to have news value it is sent out by the agencies over their wires to their respective newspaper clients for prompt publication.

Usually such announcement arouses an interest demanding fuller detail and enough general information to enable the reader to see the discovery in some of its important relationships. Such fuller accounts are frequently supplied to local news reporters by the investigator or by the head of the department on whose staff he is. Again, the Office of Publications may prepare an article of some length, based on information supplied by Institution reports and by the investigator himself, and which carries suitable illustrations.

Such articles are issued by the Institution through its organ, the *News Service Bulletin*. A Press Edition is sent to the principal newspapers and magazines of this and of foreign countries, and to news syndicating agencies and special writers, at home and abroad. Subject to the release date upon each issue, permission to publish is extended to all alike. Upon request, editors are supplied with the photographs which are reproduced in the articles.

In instances, articles thus issued are translated into the languages of other countries by various agencies and redistributed, appearing at subsequent times in the principal newspapers and magazines of the respective countries.

Usually the article appearing in the Press Edition is prepared with the needs of the Sunday magazine section of the larger newspapers in view. Many of the smaller newspapers of the country do not have the equipment for converting the illustrations into half-tone plates, neither have they the space for running an article having a length of several columns.

To meet the needs, therefore, of the smaller papers, the Office of Publications prepares a shorter statement which is illustrated by a "matrix" comprising two or three of the most suitable pictures. This shorter statement, with its illustrative matrix, from which stereotypes are cast, is sent to all the papers on the mailing list at the time that the regular Press Edition is distributed. The editor of a given paper, then, can choose between the longer and the shorter statement. Upon request, either the photographs illustrating the longer statement or the "mat" illustrating the shorter statement will be sent the editor in time to be used upon the date fixed for release of the article.

In addition to the longer and fuller statement carrying illustrations, the Press also has need for short statements relating to scientific research and discovery that are not illustrated. To meet this need, the *Clip Sheet Service* has been organized. Here again, in the preparation of the material, great care is taken to insure accuracy of statement. In point of fact, even before the short items are issued they are submitted for approval to the investigators most concerned with the researches to which they relate.

Another important use for interpretative statements issued through the medium of the *News Service Bulletin* has developed—the use by schools. When the enterprise began taking form, several hundred schools of junior and senior high school grade representing all types were selected for test. For a year each was sent a copy of the *Bulletin* as the issues appeared. The report that the articles were useful in keeping teachers and pupils abreast of the progress of scientific research was so nearly unanimous that the service was continued and extended.

In response to the expressed wish of many teachers and librarians that the *Bulletin* be put in form suitable for ready reference the practise has been instituted of indexing the issues of the School Edition at the end of each three-year period and of binding them into a single volume. Three such volumes have appeared; it is expected that the fourth will be available at the close of 1938.

A Staff Edition of the *Bulletin* is also issued which is sent to the Trustees of the Institution, to staff members, and to others who are particularly interested in the Institution's organization and personnel.

The principal article in each of the three editions is the same—a carefully prepared statement describing some important development in the research activities of the Institution, illustrated by well-selected photographs. In addition to the principal article the Staff Edition frequently carries notes and comments of special interest to the Trustees and staff.

### THE INSTITUTION LECTURES

A third important agency of interpretation consists of the lecture series, given each year at the Administration Building. As now organized, these public lectures form two series, known as the *General Lecture Series* and the *Elihu Root Lectures*.

#### THE GENERAL LECTURE SERIES

Upon the occasion of the annual meeting of the Board of Trustees in December 1909, as already mentioned, the practise was instituted of inviting



the head of a major department of the Institution to address the Trustees and their guests, which included members of the diplomatic corps and heads of various scientific agencies of the Government, on the work of his department. This procedure was followed until the fall of 1921 when, instead of the single annual lecture, given only to the Trustees and their guests, a series of three lectures, open to the public, was announced.

This *General Lecture Series*, thus initiated, and maintained to the present time, has become an important factor in the interpretative activities of the Institution. Each year, since inauguration of it, at least three lectures have been given; frequently the number has reached five or more, while one year, eleven were offered. The aggregate during the period, approximately 100 lectures, has quite adequately covered the work of the Institution.

Since 1927 responsibility for submitting recommendations as to lecture programs and, after adoption, for supervising their presentation has been vested in a Committee on Lectures appointed annually by the President.

As developed by the Committee, successive lectures are grouped, occasionally, to present related subjects; for the most part, however, they are independent of one another, each treating a single research. In nearly every case these lectures have been made widely available through magazines, through the releases published by the Institution, and through reprints appearing in the *Supplementary Publications Series*, also issued by the Institution.

The objective of this general lecture series is that of affording explanation and interpretation of specific researches or of related researches as conducted by the Institution. In consequence, the Committee, in selecting lecturers, confines itself to staff members and Research Associates of the Institution.

#### THE ELIHU ROOT LECTURES

The lecturers appearing in the *General Lecture Series* devote their time, for the most part, to describing the particular projects upon which they are engaged and to presenting the conclusions to which their investigations point; they rarely turn aside from the details of their researches to discuss the philosophical aspects of their work. Yet the intensified discussion of recent years, wherein science has been sharply challenged as to its values, has suggested the need of a type of lecture which shall be devoted to consideration of the relations of science to social questions.

In response, therefore, to recognition of this need, upon recommendation of President Merriam, the Trustees of the Institution, in 1934, made provision for lectures to be given, when distinguished scholars from whatever places are available, on the general subject of the influence of science and research on current thought.

The series was designated the *Elihu Root Lectures*, in honor of Mr. Elihu Root, who, from the founding of Carnegie Institution, has been a Trustee and, for twenty-three years, Chairman of the Board.

In commenting upon this action of the Board and in explanation of it, President Merriam has said:

"In establishing this lecture series the Trustees wished to recognize especially the influence on the work of the Institution, and upon the thought of the country, exerted by Mr. Elihu Root, who, through the whole history of the Institution, has been a guide and counsellor of unusual vision and of exceptional wisdom. Among those who have known the interest of Mr. Root in the development of science, and in its deeper meaning for life and civilization, there can be no doubt that this influence has been one of the most important factors aiding to guide science along the safest paths."

Two lectures in the series were given in 1934:

*Popular and Unpopular Science*, by James R. Angell, President Yale University.

*The Nature of Progress in Science*, by H. A. Spoehr, Chairman Division of Plant Biology, Carnegie Institution.

During 1935 only one lecture was offered:

*The History of Science and the Problems of Today*, by George Sarton, Division of Historical Research, Carnegie Institution.

These lectures, published by the Institution in its *Supplementary Publications Series*, have been widely distributed.

#### OTHER INTERPRETATIVE ACTIVITIES

The foregoing statement covers the means which have been developed at the central office in Washington for informing the public about the activities of the Institution. In addition, it should be stated that members of the staff are frequently being invited to lecture on their work, to give radio talks on their investigations, to prepare articles for current magazines, and, in some instances, to write books to be brought out by commercial publishers.

Moreover, certain departments of the Institution's organization have taken steps looking toward informing the people of their respective localities about the work which they are doing. Thus, for example, Mount Wilson Observatory invites the general public to its plant on Mount Wilson one evening each week. Talks are given on astronomical subjects and opportunity is afforded for examining the equipment and viewing some of the objects revealed by the telescopes. So valuable is this contact with the public deemed to be that construction has been begun upon a building which will contain an assembly room and exhibition hall where explanations and interpretations of the work of the observatory can be made more satisfactorily.

So, too, the Department of Genetics, in 1929, on the occasion of the twenty-fifth anniversary of the inauguration of the research activities of Carnegie Institution held an exhibition at the department headquarters, Cold Spring Harbor, Long Island. Certain exhibits, supplied by various departments of the Institution, which were displayed, were designed to show what the principal fields of knowledge are in which the Institution is conducting research. For the most part, however, the exhibits were intended to illustrate the specific work of the department, particularly that part of it which bears upon the question: what makes differences in living things?

Also during 1929, the Department of Terrestrial Magnetism, as a part of the twenty-fifth anniversary, held an exhibition on board the ship *Carnegie*, at that time in the harbor of San Francisco. The construction of this unusual vessel was described, the operation of the highly specialized instruments with which the vessel was equipped was demonstrated, and the purposes for which the vessel had been built were explained.

This sketch of the efforts which the Institution is making to interpret its work would by no means be complete without mention of the report on the progress of activities in the Institution which the President annually transmits to the Board of Trustees. The Year Book, as it is called, which contains this report, consists of detailed statements by department heads and individual grantees on the work of the year. These are accompanied by extended remarks by the President wherein attention is directed to the most significant accomplishments of the year, to question of Institution policies as these relate to the planning and prosecution of the research program, and to such philosophical considerations as the work of the year suggests.

The Year Book series, now numbering thirty-five volumes, is the most comprehensive statement in existence concerning the work of the Institution. Taken together these volumes compose an extremely valuable record covering the inception and progress of the investigations undertaken. In the aggregate they form a rich mine of information relating to the progress of research as conducted by Carnegie Institution.

In general the departmental reports and the reports of grantees, contained in the series, deal with details of research activities. So diversified are they that, viewed by themselves, they might readily suggest lack of homogeneity in the work of the Institution.

The expository comments by the Presidents contained in the volumes, however, serve to set in convincing light the fact that the Institution, although functioning in many directions, is an organic whole, having unity of purpose and proceeding, from the time of its founding, in accordance with carefully considered, well-defined plans. Moreover, the interpretational comments by the successive Presidents reveal, as nowhere else, that, while preserving continuity of purpose and of practise, sensitive response has been made to changing conditions in the field of scientific research, brought about by increase of knowledge and by change in conceptions of the social values to be derived from the fruits of research.

It has been said that our existing structure of civilization is based upon science and that our hope of progress turns upon our ability to apply science and the scientific method to the organization of society and to the various separate social problems that are continually arising. It is pointed out that we need not only to foster scientific research in the narrow specialized sense, but we need also to plan scientifically, with an experimental basis wherever possible, and always under check of scientifically ascertained facts.

The disposition so to proceed presumes the existence of a science-minded people, a people who appreciate and understand science, who possess a broad scientific outlook on life, who naturally look to science and its

method for aid in meeting new problems as they arise. The means that Carnegie Institution is employing to inform the public about its activities in the field of scientific research, as described in the foregoing sketch, represent its contribution to the great undertaking of making our people science-minded. The considerations supporting this point of view are set forth in detail and with clarity and cogency in those reports of President Merriam especially which have been transmitted during the last decade.

The Statistics of Publications and the Bibliography follow.

## STATISTICS OF PUBLICATIONS

The table which follows gives the Institution's yearly production of monographic publications now totaling 687 volumes, comprising 204,115 pages of printed matter.

*Production of Monographic Publications*

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902 .....	3	46	.....	46
1903 .....	3	1,667	.....	1,667
1904 .....	11	2,843	34	2,877
1905 .....	21	3,783	1,445	5,228
1906 .....	19	3,166	1,288	4,454
1907 .....	38	6,284	3,428	9,712
1908 .....	28	4,843	2,485	7,328
1909 .....	19	3,695	1,212	4,907
1910 .....	29	3,274	4,831	8,105
1911 .....	30	5,062	1,670	6,732
1912 .....	23	3,981	2,044	6,025
1913 .....	29	6,605	2,752	9,357
1914 .....	23	4,978	1,934	6,912
1915 .....	23	4,686	1,466	6,152
1916 .....	35	9,478	2,430	11,908
1917 .....	21	4,464	2,691	7,155
1918 .....	17	3,073	1,120	4,193
1919 .....	29	5,834	2,431	8,265
1920 .....	23	3,962	3,710	7,672
1921 .....	18	4,068	1,398	5,466
1922 .....	24	4,566	2,039	6,605
1923 .....	20	6,459	604	7,063
1924 .....	17	4,665	834	5,499
1925 .....	24	3,970	1,277	5,247
1926 .....	14	4,552	850	5,402
1927 .....	17	4,520	2,089	6,609
1928 .....	15	4,495	1,044	5,539
1929 .....	12	4,938	452	5,390
1930 .....	15	4,096	844	4,940
1931 .....	14	4,017	1,343	5,360
1932 .....	16	2,155	2,588	4,743
1933 .....	22	4,256	1,370	5,626
1934 .....	13	3,030	1,206	4,236
1935 .....	9	1,742	813	2,555
1936 .....	13	3,395	1,745	5,140
Total...	687	146,648	57,467	204,115

In addition, during the year, the Institution has issued the following: Eight numbers in its *Supplementary Publications Series*, comprising 19 articles, chiefly Institution lectures, totaling 287 printed pages, illustrated with many cuts; 11 numbers of the *News Service Bulletin*, totaling 109 printed pages and carrying 93 illustrations; and 8 numbers of the *Clip Sheet*, containing 28 short articles relating to the work of the Institution, suitable for use of the press.

*Receipts from Sales of Publications*

Year	Index Medicus	Year Book	Miscellaneous Books
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
1933.....	50.20	69.89	4,294.83
1934.....	81.60	50.31	4,500.51
1935.....	29.00	73.28	4,118.52
1936.....	16.40	71.10	5,639.99
Total.....	111,687.10	2,166.63	212,167.06

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| No. 29. The Return to the Desert.<br>Magnetic Disturbances at the Poles.<br>The Struggle Between Forest and Prairie.<br>Benefits of Volcanic Activity. | No. 33. Extending "the Period of the Prime."<br>Method of the Astronomer.<br>Letter of an Archaeologist.   |

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# INDEX

- A-type Stars, 179, 184  
 Aberle, Sophie D., ix  
 Aboriginal American History, ix, 60, 111-146  
 Adams, Miss, Studies in Yucatan, 125, 150  
 Adams, Edward F., Solar Research, 164, 169  
 Adams, L. H., vii  
   Publications by, 105, 108, 398  
 Adams, Walter S., Astronomical Research, vii, 157, 162, 178, 180, 182, 234, 343, 355  
   Publications by, 393, 400  
 Adelaide Observatory, 262  
 Agassiz, Alexander, vi, xii  
 Albertson, Walter, Rare Earth Studies, 165, 189.  
   Publications by, 400  
 Albrecht, Sebastian, ix  
 Algol Variables, 160, 179  
 Allen, E. T., Thermal Springs Investigations, 68, 104  
   Publication by, 391, 393  
 Alpine Laboratory, 221, 234  
 Alter, Dinsmore, Climatic Cycles, 234  
 American Museum of Natural History, Co-operation of, 304  
 Anatomy, Studies in, 32  
 Anderson, C. D., Studies in Physics, 352  
   Publications by, 411  
 Anderson, Ernest, Studies in Wood Chemistry, ix, 206  
   Publications by, 403, 404  
 Anderson, John A., High-excitation Spectra Investigations, vii, 163, 191, 379  
 Anderson, William E., Nutrition Studies, 309  
 Andrade, Manuel J., Linguistic Studies, ix, 61, 64, 114, 134  
 Andromeda Nebula, 18, 158  
 Angell, James R., Lecture by, 285  
 Animal Biology, Division of, viii, 50, 394  
   Report of Chairman of, 3  
 Anteros, 174  
 Antevs, Ernst, Climatic Studies, ix, 316, 322  
 Anthropology, Studies in, 60, 65, 67, 114, 140, 142, 143  
 Apia Observatory, 271  
 Archaeology, Studies in, 68, 111, 365  
   Report on, 281  
 Architectural Survey, 122  
 Arnold, Ralph, Seismological Studies, 379  
 Astronomical Research, 13, 157, 279  
   Maya, 152  
 Atmospheric Electricity, 243, 305, 341  
 Atomic Research, 51, 253  
 Auditors, Report of, xxv  
 Auroral Relations, 238  
 Avery, A. G., Datura Investigations, viii, 37  
   Publications by, 396  
 Axelrod, D., Pliocene Flora, Studies of, 227  
 Ayers, Alden F., Apparatus Construction by, 194  
 Ayers, Frank, Studies in Geology, 325  
 B-type Stars, 159, 165, 177, 180, 183, 184  
 Baade, Walter, Stellar Investigations, vii, 163, 176, 184, 185, 186, 188  
   Publications by, 401  
 Babcock, E. B., Studies in Genetics, ix, 302, 303  
   Publications by, 404, 409  
 Babcock, Harold D., Ruling Machines, 192  
   Solar Research, vii, 163, 164, 169  
   Publications by, 401  
 Babcock, Horace, Solar Chromosphere, Observations of, 165  
   Publications by, 401  
 Bailey, Austin, Magnetic Activity, 240  
 Bailey, I. W., Studies in Wood Chemistry, ix, 206, 208, 234  
   Publication by, 404  
 Baird, H. F., 272  
   Publication by, 405  
 Baker, Milo S., Cytological Investigations, 213  
 Baldwin, George J., vi  
 Balsam, Ella, Observatory-work, 263  
 Barach, Alvan L., Cooperation of, 56, 7, 71, 76  
 Barbour, Thomas, v, xix  
 Barnes, B. O., Prolactin Studies, 52  
 Barroll, M. K., Cooperation of, 252  
 Bartels, J., Magnetic Studies, ix, 234, 236, 240, 259, 277, 278, 342  
   Publications by, 405  
 Barth, Tom. F. W., Publications by, 106, 107, 398  
 Bartholomew, J. R., Cooperation of, 286  
 Bartlett, Robert, Studies on Diatomaceæ, 287  
 Barton, L. V., Mutation Studies, 38, 39  
 Basket Makers, 49, 142, 143, 229  
 Bassett, P. R., Cooperation of, 259  
 Bassler, R. S., Studies in Geology, 332  
 Bates, R. W., Endocrine Studies, viii, 49-53  
   Publications by, 396, 397  
 Bauer, L. A., vii  
 Beebe, A. N., Mount Wilson Construction Work, 193, 194  
 Bell, James F., v, xix  
 Bell Telephone System, Cooperation of, 246  
 Benedict, F. G., Nutrition Studies, viii, 55, 60, 68, 56, 68, 72, 114, 315  
   Lectures by, 72  
   Papers by, 76  
   Publications by, 77-80, 390, 392, 396, 398  
   Report of Nutrition Laboratory, 70  
 Benioff, Hugo, Seismological Research, vii, 269  
   Publication by, 370, 409  
 Benjamin, J. A., Studies in Animal Biology, 32  
   Publication by, 394, 395  
 Bennett, R. D., Studies in Physics, 270, 343, 345, 346  
 Bensley, Edward H., Cooperation of, 55, 7, 71, 73  
 Bequaert, J., Publication by, 391  
 Berger, C. A., Cytological Studies, 13, 14  
   Publication by, 394  
 Bergner, A. D., Datura Investigations, viii, 37  
   Publications by, 396  
 Berkner, L. V., Magnetic Studies, vii, 234, 249-251  
   Publications by, 405, 408

- Biesecker, Earle B., x  
 Billings, John S., vi, xii, xiii  
 Biochemical Investigations, 198  
 Biological Results, 276  
 Biology, Report on, 283  
 Bjerknes, J., Studies in Meteorology, 307  
 Bjerknes, V., Studies in Meteorology, ix, 8, 305, 306  
 Blakeslee, A. F., Racial Studies, viii, 69, 72  
     Publications by, 306  
     Report of Department of Genetics, 37  
 Bleakney, Walker, Studies in Chemistry, 299  
 Bleick, W. E., Nuclear Studies, 260  
     Publication by, 407  
 Bliss, Robert Woods, v, xix  
 Bliss, Wesley, Cooperation of, 320  
 Block, Richard J., Publication by, 410  
 Blossom, Philip, Mammalian Studies, 288  
 Bode, F. D., Studies in Geology, 331  
     Publication by, 319  
 Boötis, 178, 185  
 Boss, Benjamin, Stellar Research, viii, 179, 180  
 Boss, Lewis, viii  
 Bowen, N. L., Studies in Physics, vii, 350  
     Publications by, 103, 107, 399  
 Boyd, Amélie, Studies in Animal Biology, 29  
     Publication by, 394  
 Boyd, J. D., Organogenesis, 11  
 Boyden, A. A., Studies of Invertebrates, 81, 82  
 Bramhall, E. H., Ionospheric Studies, 250, 252, 273  
 Brankamp, R. A., Point Lobos Studies, 365  
 Brand, Donald D., Cooperation of, 320  
 Brayton, Ada M., Stellar Research, 164, 178  
 Breder, C. M., Publication by, 390  
 Breit, G., Magnetic Studies, ix, 248, 255-257, 260  
     Publications by, 405-408  
 Bridges, C. B., Studies in Heredity, ix, 289-293, 297  
     Publications by, 411  
 British Admiralty, Cooperation with, 276, 277  
 Bronikowski, N., Biological Results, 276  
 Brookings, Robert S., vi  
 Brown, Claudeus J. D., Publication by, 391  
 Brown, F. C., Magnetic Observations, 259, 262  
 Bruhn, J. M., Paper by, 76  
     Publication by, 78, 398  
 Buchholz, J. T., Datura Investigations, 37  
     Publication by, 396  
 Bunker, Frank F., x, 279  
     Report of Editor, 380  
 Bunnell, C. E., Cooperation of, 252  
 Burbridge, P. W., Cooperation of, 341, 346  
 Burlew, John S., vii  
 Burnett, Edmund C., United States Historical Research, ix, 66, 67, 147  
     Publication by, 389  
 Burt, W. H., Mammalian Studies, 287  
 Burwell, Cora G., Stellar Research, 164, 180  
 Butcher, E. O., Hormone Studies, 27, 34  
     Publications by, 394  
 Buwalda, John P., Studies in Geology, ix, 316, 321, 379  
     Lunar Investigations, 355  
 By-laws of the Institution, xv  
 Byrd Expeditions, 238, 279  
 Cadwalader, John L., vi, xii  
 California Institute of Technology, 21, 162, 187, 192, 316, 317, 319, 321, 329, 331, 342, 349, 377  
 Callaway, Samuel, x  
 Cambium Studies, 208  
 Campbell, A. S., Oceanographic Work, 276  
 Campbell, Douglas H., Point Lobos Studies, 366  
 Campbell, H. L., Publication by, 411  
 Campbell, Ian, Archean Rocks, Study of, 317, 329  
     Publication by, 409  
 Campbell, W. W., Seismological Research, v, 379  
 Campeche, Exploration in, 120, 122, 124, 125, 151  
 Canadian Meteorological Service, Earth-current Study, 246  
 Capello, J. J., Studies in Terrestrial Magnetism, 278, 280  
 Capricorni, 160, 179  
 Carlson, Dorothy J., Stellar Investigations, 164, 182  
 Carnegie, Andrew, xi, xiii, 279, 380  
*Carnegie, The*, 32, 34, 245, 262, 275-278, 280, 386  
 Carnegie Corporation of New York, xi, 13, 10, 49, 281, 298, 314, 327, 349, 359, 364, 367  
 Carpenter, T. M., Study of *Macacus Rhesus*, viii, 71-73  
     Lectures by, 72  
     Publications by, 77, 398  
 Cartledge, J. L., Datura Investigations, 37, 39  
     Publication by, 396  
 Carty, John J., vi  
 Cary, L. R., Study of Tissue Cells, 81, 83  
 Caso, Alfonso, Archaeological Studies, 281  
 Castle, W. E., Studies in Biology, ix, 74, 283  
     Publications by, 409  
 Catterall, Helen T., Publication by, 68, 389  
 Cenozoic Period, 226  
 Cepheid Variables, 160, 163, 178, 186  
 Ceramic Studies, 61, 62, 114, 115, 142-144  
 Ceti, 179  
*Challenger, The*, 32, 101  
 Chamberlain, R., Spanish Archives, Study of, 151  
 Chaney, R. W., Studies in Paleobotany, ix, 12, 225, 234, 365, 366  
     Publications by, 392, 393, 404  
 Chapman, S., Cooperation with, ix, 25, 164, 234, 236, 239, 259  
     Publications by, 405  
 Cheltenham Observatory, 241, 242, 262, 263, 273, 341-343, 345  
 Chemistry, Report on, 298  
 Chesterfield Inlet, 239, 240  
 Chibnall, Albert Charles, Studies in Nutrition, 311, 313  
     Publication by, 411  
 Chichen Itza, 118, 120-125, 131, 141, 145  
 Child Development Studies, 53, 5, 67, 140, 304  
 Chimpanzee, Study of, 25, 78

- Christchurch Observatory, 273, 341, 343, 345  
 Christie, William H., Stellar Research, 164,  
 176, 178, 179, 184, 192  
 Publications by, 401  
 Chromosomes, Study of, 51, 13, 15, 37-44, 61-63,  
 140, 283, 289-292, 294-297, 302  
 Chrysler, M. A., Cycadeoid Studies, 339  
 Clancy, C. W., Biological Research, 297  
 Clark, Frank H., Mammalian Studies, 287,  
 289  
 Publications by, 410  
 Clark, H. E., Studies in Nutrition, 313  
 Publications by, 410, 411  
 Clausen, Jens, Experimental Taxonomy, VIII,  
 48, 208, 213  
 Clements, E. S., Studies in Ecology, 223  
 Clements, F. E., Studies in Ecology, VIII, 12,  
 47, 221-223, 234, 365  
 Publications by, 392, 404  
 Clench, W. J., Publication by, 391  
 Climatological Research, 198, 223, 227, 322  
 Clip Sheet Service, 383, 388, 393  
 Coast and Geodetic Survey, Cooperation of,  
 37, 7, 50, 237, 238, 242, 246, 272, 273,  
 341, 368, 369, 378  
 Colbert, Edwin H., Geological Studies, 328  
 Cole, Whiteford R., VI  
 College, Alaska, 273  
 Collins, Guy, Maya Agronomy, Studies of, 61,  
 114  
 Collip, J. B., Hormone Studies, 49, 50, 52  
 Colors of Stars, 175-177, 186  
 Colovos, N. F., Studies in Animal Biology, 72,  
 75  
 Publication by, 78, 398  
 Compton, A. H., Magnetic Studies, IX, 259,  
 270, 273, 341-343  
 Publication by, 410  
 Condit, C., Studies in Paleobotany, 226, 365  
 Condon, E. U., Atomic Physics, 255, 260, 261  
 Publication by, 405, 406  
 Conger, Paul S., Studies on Diatomaceae, IX,  
 285  
 Connor, Elizabeth, 164  
 Consanguinity, Measure of, 62, 63  
 Copan, Excavations at, 62-64, 115, 117  
 Cornwall, Elizabeth R., 164  
 Coropatchinsky, V., Respiratory Studies, VIII,  
 73, 75, 76  
 Cosmic-ray Studies, 245, 270, 273, 341, 343,  
 345, 346, 348, 349, 351, 352  
 Cotton, Jack C., Studies in Physiology, 361-363  
 Cowie, D. B., Studies in Physics, 349  
 Cowperthwait, Arthur N., Chronological Stud-  
 ies, 230  
 Cranston, Harriet, Studies in Anthropology,  
 67  
 Creaser, Edwin P., Publication by, 391  
 Crocker, William, Mutation Studies, 39  
 Cross, Paul C., Studies in Chemistry, 298  
 Cummins, Harold, Publication by, 396  
 Curry, Robert O. L., Studies in Physiology,  
 360  
 Curti, Margaret W., Publication by, 396  
 Cycadeoid Investigations, 333  
 Cycle Studies, 228, 234, 235  
 Cytological Studies, 4, 13, 16, 41, 54, 140, 289,  
 293, 294, 302-304  
 Dahl, O., Nuclear-physics Studies, 259, 260  
 Publications by, 406, 408  
 Dalton, John S., 194  
 Daly, Blanche B., Nutrition Studies, 77  
 Darby, H. H., Crustacea Studies, 81, 83  
 Publications by, 390  
 Darlington, P. J., Publication by, 391  
 Datura Studies, 51, 4, 37  
 Daugherty, L. H., Paleobotany, 226  
 Davenport, Charles B., Child Development  
 Studies, VIII, IX, 304  
 Publications by, 410  
 Davies, F. T., Magnetic Studies, VII, 234  
 Publications by, 406, 408  
 Davis, H. F., Plant Photography, 230  
 Dawson, C. A., Biological Results, 276  
 Day, Arthur L., Physics, Research in, VII, 29,  
 51, 35-37, 68, 355, 379  
 Publication by, 391  
 Report of Geophysical Laboratory, 97  
 deChardin, Teilhard, Geological Studies, 327  
 DeGaris, C. F., Inheritance Studies, 13, 33, 34  
 Publications by, 394, 395  
 deHuff, Kenneth, Mount Wilson Construction  
 Work, 194  
 Delano, Frederic A., v, XIX, XXII  
 deLaubenfels, M. W., Study of Sponges, 81, 86  
 Publication by, 391  
 Dellinger, J. H., Radio Studies, 172  
 Demerec, M., Study of the Gene, VIII, 40  
 Publications by, 396  
 Dental Studies, 67, 68  
 Desert Laboratory, VIII, 47, 49, 60, 114, 197,  
 213, 214, 217-220, 230  
 deTerra, H., Studies in Geology, IX, 316, 325,  
 327-329  
 Dewey, Mrs. G., Tree Studies, 230, 273  
 Diatomaceae, Studies of, 285  
 Dice, Lee R., Studies in Ecology, IX, 287  
 Publication by, 410  
 Dill, D. B., Respiratory Studies, 71, 73  
 Doan, R. L., Studies in Physics, 341, 345  
 Publications by, 410  
 Dobzhansky, Th., Studies in Biology, 291, 293  
 Dodge, Cleveland H., VI, XII  
 Dodge, Frank, Cooperation of, 331  
 Dodge, William E., VI  
 Doe, R., Studies in Animal Biology, 77  
 Dorf, E., Study of Paleobotany, 226, 227  
 Dotti, Louis B., Hormone Studies, 50  
 Dougherty, Paul, Point Lobos Studies, 366  
 Douglass, A. E., Climatological Research, IX,  
 48, 227, 234  
 Publication by, 404  
 Doyle, W. L., Cytological Study, 14  
 Publications by, 390, 394  
 Drager, William, Studies in Child Develop-  
 ment, 304  
 Publication by, 410  
 Drosophila, Study of, 51, 4, 40, 43, 289, 294,  
 296, 297  
 Drummond, J., Geological Studies, 327, 328  
 Drury, Aubrey, Point Lobos Studies, 365  
 Drury, Newton B., Point Lobos Studies, 366  
 Duel, A. B., Studies in Animal Biology, 30

- Duncan, John C., Stellar Research, 159, 165, 182, 184  
     Publication by, 401
- Dunham, Theodore Jr., Stellar Research, VII, 163, 164, 167, 178, 182, 185  
     Publication by, 401, 402
- Duvall, C. R., Land Magnetic Survey, VII, 261, 262
- Dyer, W. R., Magnetic Studies, 272
- Early Man, Studies of, 316, 323
- Earthquake Activity, 371-379
- Earth's Magnetic Field, 28, 231-279
- Ecology, Studies in, VIII, 221, 287
- Edwards, H. T., Respiratory Studies, 71, 73
- Electrically Exploded Wires, 191
- Elephant, Study of, 68, 73
- Eliax, M. K., Studies of Paleobotany, 226  
     Publication by, 392
- Elihu Root Lectures, 383-385, 392
- Ellerman, Ferdinand, Solar Studies, 163, 167
- Ellestad, R. B., Publication by, 107, 399
- Embryo, Human, 10
- Embryology, Department of, VIII, 50, 52, 56, 57, 73, 394  
     Report of Department of, 9
- Emission Lines, 190
- Endocrine Studies, 49
- Ennis, C. C., Observatory-work, VII, 234, 263  
     Publications by, 406
- Eocene Period, 198, 225, 226
- Epstein, P. S., Studies in Physics, 355
- Eros Stars, 175
- Ethnological Research, 64, 131
- Eugenics Record Office, VIII, 50, 3, 7, 56, 61, 62
- Eugenics, Studies in, 56
- Evolution, Station for Experimental, VIII, 50, 3
- Executive Committee, Report of, XXI
- Exhibition, Annual, 381
- F-type Stars, 184
- Fenner, C. N., VII  
     Publications by, 103, 104, 399
- Fenner, Charles P., VI
- Ferguson, Homer L., V, XIX, XXII
- Figgins, J. D., Studies of Early Man, 323
- Financial Statement, XXII  
     Balance Sheet, XXVI  
     Real Estate, XXXIII  
     Receipts and Disbursements, XXIII, XXVII  
     Securities Schedule, XXVIII-XXXII
- Findley, M. D., Leukemic Studies, 45
- Fireman, Milton, Publication by, 403, 404
- Fisher, W. K., Biological Results, 276, 365
- Fleischer, Michael, VII
- Fleming, John A., Magnetic Research, VII, 234, 273, 278, 343, 349  
     Report of Department of Terrestrial Magnetism, 231  
     Publications by, 406
- Fleming, R. H., Biological Results, 276
- Flexner, L. B., Organogenesis, Studies in, 11, 28
- Flexner, Simon, VI
- Foley, J. P. Jr., Study of Macaque, 26  
     Publication by, 394
- Fontaine, P. N., Chichen Itza, Studies in, 121
- Forbes, W. Cameron, V, XIX, XXI, XXII
- Forbush, S. E., Magnetic Studies, VII, 234, 243, 261, 263, 273, 341, 345
- Fraser, H. J., Cooperation of, 331
- Frew, William N., VI, XII
- Frick, Childs, Studies of Pliocene Flora, 227
- Fruit Fly, Study of, 58
- Furlong, E. L., Geological Studies, 320
- Furtos, Norma C., Publication by, 391
- G-type Stars, 179
- Gage, Lyman J., VI, XII
- Gaige, Helen Thompson, Publication by, 391
- Galactic Studies, 184, 344
- Galilee, The, 262
- Gallo, J., Studies in Physics, 341
- Gamow, G., IX  
     Publications by, 406
- Garven, H. S. D., Publication by, 77, 398
- Gates, W. H., Publications by, 409
- Geiling, E. M. K., Studies in Physiology, 21, 26, 27, 31, 34  
     Publications by, 394
- Gene, Study of, 51, 40, 283, 291
- Genetics, Department of, VIII, 50, 52-54, 60, 61, 114, 140, 385, 396  
     Report of Department of Genetics, 37
- Genetics, Human, 67
- Genetics, Studies in, 287, 302
- Geography, Human, 140
- Geology, Study of, 316-340
- Geomagnetic Coordinates, 236
- Geophysical Laboratory, VII, 9, 29, 60, 114, 398  
     Report of Geophysical Laboratory, 97
- Germ-cells, Study of, 16
- Gersh, L., Study of Organogenesis, 11, 16, 21, 22  
     Publication by, 394
- Gey, G. O., Studies in Animal Biology, 18, 19  
     Publication by, 394
- Gey, M. K., Studies in Animal Biology, 18, 19  
     Publication by, 394
- Gibson, R. E., VII  
     Publications by, 106, 108, 393, 399
- Gifford, Walter S., V, XIX, XXII
- Gilbert, Cass, VI
- Gilbert, W. M. x, 72
- Gillett, Frederick H., VI
- Gilman, Daniel Coit, VI, XII, XIII
- Gish, O. H., Magnetic Studies, VII, 231, 243, 246, 278  
     Publications by, 393, 406
- Glidden, E. M., Study of Chimpanzee, 33  
     Publication by, 394
- Globular Clusters, 176
- Glock, W. S., Chronological Studies, VIII, 230  
     Publications by, 404
- Godske, C. L., Study of Meteorology, 307
- Golder, Frank A., United States Historical Research, 147
- Goranson, Roy W., VII  
     Publication by, 108, 399
- Graham, H. W., Biological Results, 276, 278
- Grave, Caswell, Tortugas Laboratory, Researches in, 81, 84, 87, 88  
     Publication by, 390
- Greek Thought, History of, 155
- Green, C. V., Study of the Gene, 283



- Green, John W., Magnetic Studies, VII, 261, 262, 267  
Publication by, 406
- Gregory, W. K., Geological Research, 328
- Greig, J. W., Pottery Studies, VII, 144  
Publication by, 109, 399
- Grey, Irving M., x
- Griffin, Allen, Point Lobos Studies, 366
- Grinnell, J., Vertebrate Studies, 364
- Guatemala, Studies in, 62, 63, 65, 114-146, 151
- Gutenberg, B., Studies in Seismology, 375  
Publications by, 379, 409
- Hafstad, L. R., Magnetic Studies, VII, 259-261  
Publications by, 407
- Haight, Frank J., Publication by, 390
- Hale, George E., Solar Research, VII, 157, 162, 164, 173, 380  
Publications by, 401
- Hall, F. G., Studies in Plant Biology, 44, 61 114, 120, 208, 212  
Publication by, 390
- Hamburg Observatory, 185
- Hamilton, Anna, Studies in Genetics, 304
- Hamlett, G. W. D., Study of Animal Biology, 12  
Publication by, 394
- Hanke, Lewis, Historical Research, 151
- Hansen, A. T., Ethnological Research, 64, 131, 132
- Harper, W. W., Publication by, 411
- Harradon, H. D., Bibliographies, 279  
Publications by, 407
- Harrington, J. C., Exploration in Campeche, 125, 127
- Harrington, Johns, Geological Studies, 320
- Harrington, M. R., Studies of Early Man, IX, 316, 320
- Harris, J. E., Publication by, 390
- Hartman, C. G., Reproduction Studies, VIII, 4, 23-25, 71, 72, 360  
Publications by, 394
- Hatch, C., Physiological Studies, 74, 75
- Hay, John, VI, XII, XIII
- Hayden, James J., United States Historical Research, 68, 147  
Publication by, 389
- Haynes, S. K., Cosmic-ray Investigations, 351
- Heidel, W. A., History of Greek Thought, IX, 155, 156
- Hellmann, M., Studies in Palaeontology, 328
- Hendrick, Joyce, Publication by, 391
- Hendrix, D. O., Observatory-work, 194, 263, 280
- Herb, R. G., High Voltage Studies, 257, 259
- Heredity, Studies in, 56, 283, 289
- Herrick, Myron T., VI
- Hertig, Marshall, Studies of Diatomaceae, 287
- Hess, V. F., Cosmic-ray Research, 343, 344
- Heuser, C. H., Study of Organogenesis, VIII, 11  
Publication by, 394
- Hewitt, Abram S., VI
- Heydenburg, N. P., Magnetic Studies, 259-261  
Publication by, 407, 408
- Heyworth, D., Studies in Physics, 345, 346
- Hibben, Frank C., Cooperation of, 320
- Hibben, James H., VII  
Publication by, 105, 399
- Hickox, Joseph, Solar Research, 164, 167  
Publication by, 401
- Hiesey, William M., Experimental Taxonomy, VIII, 45, 208, 212, 213
- Higginson, Henry L., VI, XII
- Hinckley, A. L., Desert Investigations, 217
- Hinds, N. E. A., Geological Studies, x, 317, 331  
Publication by, 391
- Hines, M., Study of Nerves, 4, 29  
Publication by, 394, 395
- Historical Research, Division of, IX, 56, 279, 399  
Report of Chairman of Division, 111
- Historical Research, 281
- Hitchcock, Ethan A., VI, XII, XIII
- Hitchcock, Henry, VI
- Hoge, Wendell P., Infra-red Solar Studies, 164, 169  
Publication by, 401
- Honduras, Studies in, 62-64, 115, 117, 127, 136
- Hooton, E. A., Southwestern Research, 143
- Hoover, Herbert, v, XIX
- Hoover, Margaret E., The Gene, Study of, 40, 43  
Publications by, 396
- Hormone Studies, 51, 6, 23, 26, 49-54, 84, 297
- Horse, Study of, 7, 64-66, 75
- Howard, Edgar B., Study of Early Man, x, 316, 323-325  
Publication by, 393
- Howard, Hildegard, Geological Studies, 320
- Howe, H. A., Study of Macaque Monkeys, 30, 31  
Publications by, 394, 395
- Howe, William Wirt, VI, XII
- Howell, Brazier, Anatomy, Studies of, 32, 33  
Publications by, 394
- Hrubetz, M. Caroline, Studies in Animal Biology, 40
- Huancayo Observatory, 239, 240, 247-253, 268, 273-275, 280, 341-345
- Hubbell, Rebecca B., Studies in Nutrition, 313  
Publication by, 410
- Hubble, Edwin P., Astronomical Research, VII, 17, 158, 163, 174, 176, 182, 184, 185, 187, 188  
Publications by, 401
- Hubbs, Carl L., Publication by, 391
- Huff, C., Mechanical Designs, 252, 277
- Humason, Milton, Stellar Research, VII, 163, 174, 181, 183-188  
Publications by, 393, 400, 401
- Hungerford, H. B., Publication by, 391
- Hunter, Mrs. Robert, Point Lobos Studies, 366
- Hutchinson, Charles L., VI, XII
- Hydrography, Study of, 305
- Illing, W., Galactic Studies, 344
- Infra-red Spectrum, 169
- Ingerson, Earl, Publication by, 103, 399
- Inheritance Studies, 13
- Institute for Advanced Study, Cooperation of, 260

- International Astronomical Union, 161, 162, 166, 269
- International Meteorological Organization, 272, 278
- International Union of Geodesy and Geophysics, 236
- Ionosphere. Investigations of, 248, 251, 273, 278
- Isomagnetic Charts, 235
- Isotopes, Study of, 299
- James, B., Respiratory Studies, 73
- Jameson, J. Franklin, United States Historical Research, ix, 147
- Jeans, J. H., x
- Jenkins, Heroy, viii
- Jenkins, J. A., Studies in Genetics, 303, 304
- Jenkins, Katharine, Studies in Genetics, 304
- Jenks, J. J. Jr., Study of Elephants, 74
- Jepson, Willis O., Point Lobos Studies, 365, 366
- Jewett, Frank B., v, xix
- Jochelson, Waldemar, ix
- Johnson, E. A., Atomic Physics, 234, 260, 261, 273  
Publications by, 407, 408
- Johnson, M. W., Endocrine Studies, 49, 53, 55
- Johnson, T. H., Cosmic-ray Studies, x, 341-343, 346, 351  
Publications by, 407
- Johnston, H. F., Observatory-work, vii, 234, 263
- Jones, Sidney, Mount Wilson Construction Work, 194
- Joy, Alfred H., Stellar Research, vii, 163, 178, 180-182  
Publications by, 400, 401
- Joyce, J. Wallace, Magnetic Studies, 272
- Joyner, Mary C., Stellar Research, 164, 175
- Jund, E., Studies in Genetics, 304
- Jupiter, 174
- K-type Stars, 160, 177, 179
- Kaminal-juju, Excavations in, 63, 130
- Karpov, Boris, Stellar Research, 164
- Keck, David D., Experimental Taxonomy, viii, 43, 208, 214, 216  
Publications by, 393, 404
- Keeler, C. E., Studies in Genetics, 285  
Publication by, 409
- Keenan, C. G., Apparatus Construction, 230
- Kellogg, Remington, Studies in Geology, x, 316, 321
- Kemnitzner, Luis, Cooperation of, 331
- Kempton, J. H., Maya Agronomy, Investigations in, 61, 65, 114, 138, 142
- Kennelly, A. E., x  
Publication by, 407
- Kerr, Thomas, Publication by, 404
- Kidder, A. V., Historical Research, ix, 128, 130, 142  
Report of Division of Historical Research, 111  
Publications by, 390, 399
- Kilborn, L. G., Papers by, 76
- Kille, Frank R., Studies at Tortugas Laboratory, 81, 85, 93
- Killip, E. P., Publications by, 391
- King, Arthur S., Rare-earth Studies, vii, 163, 165, 182, 190  
Publications by, 400, 401
- King, R. B., Stellar Research, 163, 165, 182, 190  
Publication by, 401
- Kinney, H. S., Construction Work, Mount Wilson, 194
- Koch, P. P., Nebular Investigations, 185
- Kodaikanal Observatory, 161, 167
- Kopac, M. J., Publication by, 390
- Korff, Serge, Studies in Physics, 350  
Publications by, 411
- Koudelka, K., Study of Macacus Rhesus, 73
- Kracck, F. C., vii  
Publication by, 109, 399
- Kramp, P. L., Biological Results, 276
- Kratz, Conrad, Exploration in Campeche, 125, 127
- Kron, G. E., Stellar Research, 165
- Krznarich, Paul W., Publication by, 404
- Ksanda, C. J., vii  
Publications by, 109, 110, 399
- Kwei, C. T., Magnetic Studies, 234, 250, 262  
Publications by, 407, 408
- Laanes, T., Leukemic Studies, 45, 50  
Publication by, 396
- Lacey, J. S., Publication by, 407
- laCour, D., Magnetic Studies, 263, 264, 268
- Lahr, E. L., Endocrine Studies, 49-53  
Publications by, 396, 397
- LaMotte, Robert S., Publication by, 390
- Land Magnetic Survey, 261
- Lane, Mary Steele, Publication by, 397
- Langer, R. M., Solar Research, 164, 173  
Publication by, 401
- Langley, Samuel P., vi, xii
- Langworthy, O. R., Studies in Animal Biology, 32
- Latimer, H. H., Studies in Animal Biology, 75
- Laughlin, H. H., Heredity Studies, viii, 56  
Publications by, 393, 397
- Law, L. W., Mammalian Studies, 285  
Publications by, 409
- Lawson, A. C., Seismological Studies, 379
- Leavenworth, Charles S., Studies in Nutrition, 313  
Publication by, 411
- Leaves, Study of, 201, 204
- Lectures, 383, 384
- Ledig, P. G., Observatory-work, vii, 263
- Lee, Edward, Point Lobos Studies, 365
- Lee, G., Studies in Metabolism, 74, 75
- Lee, Milton O., Studies in Nutrition, 71, 72, 75
- Lee, R. C., Studies of Animal Biology, viii, 72-76  
Paper by, 76  
Publications by, 79, 398
- Leighton, P. A., Studies in Chemistry, x, 298  
Publication by, 410
- Leighton, W. G., Biochemical Investigations, 201
- Leitch, J. F., Study of Sea-urchins, 81
- Leitch, James L., Study of Marine Invertebrates, 87, 365  
Publications by, 390, 391

- Leland, Waldo G., United States Historical Research, 147
- Leonard, E. C., Publication by, 391
- Leraas, Harold J., Studies in Ecology, 289
- Leukemia Studies, 6, 45
- Lewis, G. E., Studies in Geology, 328
- Lewis, Margaret R., Studies in Animal Biology, VIII, 17-20, 26, 27, 34  
Publications by, 394, 395
- Lewis, W. H., Studies in Animal Biology, VIII, 20, 21  
Publication by, 395
- Li, J. C., Chromosome Studies, 292, 293
- Lichenstein, Edna G., Studies in Animal Biology, 20  
Publication by, 395
- Liebe, Margaret, Studies in Biology, 238
- Lindbergh, Charles A., v
- Lindsay, William, vi, XII
- Linguistic Investigations, 64, 114, 134
- Linsdale, J. M., Vertebrate Studies, 364
- Littlehale, A. D., Studies in Animal Biology, 75
- Locke Solution, 28
- Lodge, Henry Cabot, vi
- Long, C. N. H., Studies in Animal Biology, 52
- Long, F. L., Studies in Ecology, VIII, 221  
Publications by, 392, 404
- Longley, A. E., Chromosome Studies, 140
- Longley, W. H., VIII, x, 81
- Loomis, Alfred L., v, XIX, XXII
- Loomis, F. B., Studies in Geology, 339, 340
- Lord Kelvin, *The*, 34
- Lothrop, S. K., Investigations at Zacualpa, 68, 128  
Publication by, 392
- Low, Seth, vi, XII
- Lowe, E. A., Research in Palaeography, IX, 155
- Lozier, W. W., Studies of Isotopes, 299
- Lugn, A. L., Studies in Geology, 325
- Lunar Investigations, 173, 240, 353
- Lundell, C. L., Maya Botany and Zoology, 61, 114
- Lyra, 159, 184
- Macaque, Study of, 56, 4, 9, 10, 23, 24, 26, 30, 33, 34, 71, 72
- MacClintock, Paul, Studies in Geology, 316, 325
- MacCormack, Elizabeth, Stellar Research, 164, 178
- MacDougal, D. T., Climatological Research, ix, 68, 227, 365  
Publication by, 391
- MacDowell, E. C., Leukemic Studies, VIII, 45, 50, 72, 74  
Publications by, 392, 393, 397
- MacGinitie, H. D., Studies in Paleobotany, 226
- Mackinney, G., Publications by, 404
- MacVeagh, Wayne, vi, XII
- Madinae, Plant Biology, 197, 208, 211, 212, 214
- Magnetic Studies, 231, 236-241, 253, 261-276, 301
- Storms, 172, 236
- Field of the Sun, 173
- Mains, E. B., Publication by, 391
- Maize Investigations, 65, 138
- Mall, Franklin P., VIII
- Mallery, T. D., Studies in Plant Biology, VIII, 47, 213, 214, 216, 218, 220  
Publications by, 404
- Mammalian Studies, 11, 20, 23, 47, 51-53, 74, 75, 283, 287, 304, 308, 314, 320
- Mañé, Rubio, Documentary Research, 120, 121, 145, 150, 151
- Mann, Albert, Publication by, 390
- Mann, Jennie F., Diatom Collection, 286
- Mann, M. B., Studies in Geology, 325
- Mansfield, R. H., Magnetic Studies, 262, 263
- Manter, H. W., Publication by, 390
- Marine Geological Studies, 321
- Markee, J. E., Reproduction Studies, 4, 23, 24  
Publication by, 395
- Marsh, Frances Botkin, Publication by, 396, 397
- Marsh, Gordon, Studies of Valonia, 81, 88  
Publication by, 392
- Marshall, Ruth, Publication by, 391
- Martin, Carmel, Point Lobos Studies, 366
- Martin, Emmett V., Studies in Ecology, 221  
Publications by, 392, 404
- Mason, H. L., Point Lobos Studies, 365
- Maxson, John H., Archean Rock Studies, 317  
Publication by, 409
- Maya Indians, Study of, 57-65, 68, 67-69, 77, 78, 111-140, 150-154, 281, 282
- Mayor, Alfred G., VIII
- McCoy, Herbert N., Cooperation of, 189
- McDuffie, Duncan, Point Lobos Studies, 366
- McKee, Edwin D., Geological Research, 317, 318
- McKenzie, Alexander A., Studies in Physics, 343, 349
- McLaughlin, Andrew C., IX
- McNish, A. G., Studies in Electricity, VII, 234, 243, 244, 263  
Publications by, 407, 408
- Meinecke, E. P., Point Lobos Studies, 365
- Mellon, Andrew W., v
- Melville, James, 313
- Mendel, Lafayette B., Nutrition Investigations, 56, 309  
Publication by, 410
- Mendelian Analysis, 64
- Mendelsohn, W., Studies in Animal Biology, 18, 19  
Publication by, 395
- Meng, John J., United States Historical Research, 147
- Menke, J. F., Studies in Physiology, 34  
Publication by, 395
- Meridian Astrometry, VIII, 21
- Merriam, John C., v, x, XXII, 193, 342, 360, 365, 366, 381, 384, 387  
Report of the President, 1  
Studies in Palaeontology, 316, 320  
Publications by, 409

- Merrill, Paul W., *Stellar Research*, vii, 163, 164, 179-181, 191  
 Publications by, 401, 402
- Merwin, H. E., vii  
 Publication by, 109, 399
- Metabolism, Study of, 56, 6, 7, 55, 70-77, 308
- Meteorology, Study of, 305-307
- Metz, Charles W., *Cytological Studies*, viii, 13-16  
 Publications by, 394, 395
- Meudon Observatory, 161, 167
- Mexico, Studies in, 62, 115, 139-144, 198, 225, 227, 273, 281, 318, 335, 341, 345, 348
- Meyer, R. C., *Magnetic Studies*, 259
- Milky Way, 15, 159, 165, 177, 344, 352
- Miller, Ruth, Publication by, 397, 398
- Miller, Alden, *Studies in Palaeontology*, 320
- Miller, Carey D., *Papers* by, 76  
 Publication by, 80, 398
- Miller, Roswell, v, xix
- Miller, William W., vii
- Millikan, R. A., *Studies in Physics*, x, 341-343, 347, 349, 350-352, 379  
 Publications by, 411
- Mills, Darius O., vi, xii, xiii
- Milner, H. W., *Studies in Plant Biology*, viii, 198  
 Publication by, 404, 405
- Minkowski, Rudolf, *Stellar Research*, 165, 178, 182, 185, 190
- Miocene Studies, 225-227, 321
- Mitchell, S. A., x
- Mitchell, S. Weir, vi, xii, xiii
- Molecular Physics, 259
- Monod, J. L., *Studies in Biology*, 296
- Montague, Andrew J., vi, xix, xxi
- Monterey Cypress, 13, 364
- Moon Committee, 20
- Moore, Charlotte E., *Solar Research*, 169, 188  
 Publication by, 401, 402
- Moore, Glenn, Publication by, 401, 402
- Moore, J. Percy, Publication by, 391
- Moran, C. S., *Studies of Pigeons*, 54  
 Publication by, 397
- Morey, George W., vii  
 Publication by, 106, 392, 399
- Morgan, Henry S., v, xix
- Morgan, T. H., *Studies in Heredity*, x, 289, 296, 411
- Moritz, C. E., *Marine Embryology*, 81, 90
- Morley, Frank, x
- Morley, S. G., *Studies at Chichen Itza*, ix, 120, 131, 151
- Morley, Mrs. S. G., 121
- Morris, E. H., *Southwestern Research*, ix, 142-144
- Morrow, William W., vi, xii, xiii
- Morton, C. V., Publications by, 391
- Mossman, H. W., *Study of Organogenesis*, 11
- Mount Wilson Observatory, vii, 15-15, 19, 20, 69, 234, 253, 378, 385, 400  
 Report of Directors of, 157
- Mountain States Telephone and Telegraph Company, *Study of Earth-currents*, 273
- Mulders, G. F. W., *Solar Research*, 165
- Muratori, G., *Cytological Studies*, 16  
 Publication by, 395
- Murphy, Anna L., *Respiratory Studies*, 73
- Murray, M. J., Publication by, 398, 397
- N-type Stars, 184
- Neddermeyer, Seth, *Studies in Physics*, 352  
 Publications by, 411
- Neher, H. Victor, *Cosmic-ray Investigations*, 342, 347, 349-352  
 Publications by, 411
- Nervous System, Study of, 28
- News Service Bulletin, 382, 383, 388, 393
- Nichols, E. C., *Mechanical Designs*, 194
- Nicholson, Seth B., *Astronomical Research*, vii, 163, 166, 167, 169, 174, 234  
 Publications by, 402
- Nicoll, Paul A., *Studies at Tortugas Laboratory*, 81, 84, 87, 88
- Nolan, Laurence S., *Nutrition Studies*, 313
- Norris, E. H., *Study of Organogenesis*, 11
- Nova Aquilae, 182
- Nova Cygni, 179, 182, 183
- Nova Herculis, 13, 14, 157, 177, 179, 180
- Nova Lacertae, 13-15, 157, 177, 178, 181, 184
- Nova Ophiuchi, 181
- Nuclear Physics, 256, 259, 260, 278, 350, 352
- Nutrition Laboratory, viii, 50, 55, 60, 3, 7, 8, 56, 114, 398  
 Report of Laboratory, 70
- Nutrition, Studies in, 308
- O-type Stars, 180
- Ocean-bottom Core Samples, 101
- Oceanographic Work, 275
- Old, Marcus C., Publication by, 390
- Olmsied, Frederick L., *Point Lobos Studies*, 364
- O'Neale, Lila, *Guatemalan Textiles*, 62, 65, 115, 136
- Oosterhoff, P. Th., *Stellar Research*, 164, 171, 175  
 Publications by, 402
- Orang-utan, Study of, 35
- Organization, Plan and Scope, xi
- Organogenesis, 11
- Orion, 177
- Osborn, William Church, vi
- Osborne, Thomas B., *Nutrition Studies*, 56, 309
- Ostenson, Burton T., *Studies in Ecology*, 287
- Ostrosky, M., *Study of Nuclear Physics*, 260  
 Publications by, 407
- Ovum Studies, 10, 11, 24
- Palaeography, Research in, 155
- Palaeontology, Studies in, 68, 316-340
- Pan American Institute of Geography and History, Cooperation of, 281
- Pan American Work-map, 50-61
- Park, E. A., *Nutrition Studies*, 310
- Parkinson, Wilfred C., *Observatory-work*, vii, 262, 263, 267, 278  
 Publications by, 407
- Parnelee, James, vi
- Parsons, William Barclay, vi
- Paterson, T. T., *Study of Origin of Man*, 327-329
- Paton, Stewart, v, xix, xxii

- Paullin, Charles O., United States Historical Research, ix, 148  
     Publications by, 399  
 Payne, Fernandus, Publication by, 392  
 Peabody Museum, Cooperation of, 61, 114, 117, 143, 151  
 Pearce, A. S., Maya Research, 61, 68, 114, 120  
     Publications by, 390, 391  
 Pease, Francis G., Stellar Research, vii, 163, 177, 184, 355  
 Pepper, George W., vi  
 Perret, F. A., ix  
 Pershing, John J., v  
 Peten Region, 63, 120, 124-126  
 Peters, W. J., Cooperation with British Admiralty, ix, 277  
 Petterson, S., Studies in Meteorology, 307  
 Petterson, Hans, Geophysical Research, 32, 101  
 Pettit, Edison, Solar Research, vii, 163, 167, 169-171, 355  
     Publications by, 393, 402  
 Photometry of Iron Absorption Lines, 190  
 Photosynthesis, viii  
 Physics, Studies in, 341  
 Physiography, Report on, 356  
 Physiology, Report on, 359  
 Picard, Jean F., Research in Physics, 349  
 Pickering, William H., Studies in Physics, 351  
     Publication by, 411  
 Pigeons and Doves, Study of, 50-55  
 Piggott, Charles S., Geophysical Research, vii, 54  
     Publication by, 106, 399  
 Pitte, R. F., Studies at Tortugas Laboratory, 81, 90  
 Planetary Studies, 173  
 Plant Biology, Division of, viii, 12, 38-47, 60, 114, 234, 403  
     Report of Division, 195  
 Pleistocene Studies, 323-329  
 Pliocene Studies, 225-227, 319  
 Plough, H. H., Studies at Tortugas Laboratory, 81, 91  
 Pogo, Alexander, Chronological Studies, ix, 152  
     Publications by, 399  
 Point Barrow, 240  
 Point Lobos Studies, 13, 364-366  
 Polar Studies, 159, 175-177, 237, 239, 240, 246  
 Pollock, H. E. D., Architectural Survey, ix, 68, 122  
     Publications by, 390, 391  
 Popenoe, Dorothy, Maize Studies, 139  
 Popenoe, Wilson, Maya Agronomic Research, 61, 65, 114, 138  
 Posnjak, E., vii  
     Publication by, 109, 399  
 Potter, J. S., Leukemic Studies, viii, 45  
     Publications by, 397, 398  
 Poulson, D. F., Studies in Embryology, 294  
 Powers, Philip B. A., Publication by, 390  
 Prentice, Sydney, Palaeontological Illustrations, 321  
 Present, R. D., Atomic Physics, 255, 260  
*Princess Alice II, The*, 32, 101  
 Pritchett, Henry S., vi, xix  
 Proper Motions, 174  
 Psychology, Report on, 367  
 Public Relations, 67  
 Publications, x, 67, 260  
 Pucher, G. W., Studies in Nutrition, 311  
     Publications by, 410, 411  
 Pueblo Studies, 48, 111, 142-144, 229  
 Puuc Region, 122-125, 141  
 Quintana Roo, Exploration in, 120, 125, 132  
 Quirigua, 126  
 Rabi, I. I., Magnetic Studies, x, 301  
 Radial Velocities, 178, 186  
 Radio Studies, 172, 240, 248, 266, 349  
 Rainfall Studies, 214-219, 223  
 Raman Spectra, 105  
 Ramsey, E. M., Embryological Stages, 10  
     Publication by, 395  
 Rancho La Brea, 320  
 Rare-earth Spectra, 189  
 Raymond, Harry, viii  
 Read, D. N., Studies in Physics, 349  
 Red Shift, 187, 188  
 Redfield, Helen, Studies in Cytology, 292  
 Redfield, R., Historical Research, x, 61, 64, 114, 131, 132, 145  
 Reed, S. C., Mammalian Studies, 285  
     Publications by, 409  
 Reese, A. M., Organogenesis, Research in, 12  
 Reid, Harry Fielding, Studies in Seismology, 379  
 Reproduction Studies, 4, 23  
*Research, The*, 276, 277  
 Respiratory Studies, 73-76  
 Revelle, R., Biological Results, 276  
 Richards, Horace G., Pleistocene Studies, 317, 323  
 Richards, O. W., Tortugas Laboratory Researches, 81, 92  
     Publication by, 390  
 Richardson, L. A., Magnetic Surveys, 262  
 Richardson, Robert S., Solar Research, vii, 164, 167, 169, 171, 172  
     Publications by, 402  
 Richmond, Myrtle L., Planetary Investigations, 164, 167, 174  
     Publication by, 402  
 Richter, C. P., Studies in Animal Biology, 32  
     Publication by, 395  
 Richter, Charles F., vii  
     Seismological Research, 375  
     Publications by, 379, 409  
 Richter, M. N., Publication by, 397  
 Ricketson, O. G. Jr., Aboriginal American Historical Research, ix, 128, 130  
     Publications by, 400  
 Ricketson, Mrs., Ceramic Studies, 128, 131  
 Riddle, Oscar, Studies in Animal Biology, viii, 52, 49-55, 72  
     Publications by, 396, 397  
 Ringling Brothers-Barnum and Bailey Circus, Cooperation of, 73, 74  
 Ritzman, E. G., Studies in Metabolism, x, 55, 7, 70-72, 75  
     Publications by, 78, 398  
 Roberts, H. B., ix  
 Roberts, H. S., vii  
 Rocks, Study of, 97, 317, 329

- Rogers, R. E., vii  
 Rooney, W. J., Study of Earth-currents, vii,  
 243, 246, 247  
     Publications by, 407, 408  
 Root, Elihu, v, xii, xiii, xix, xxii  
 Root, Howard F., 66, 7, 71, 73  
 Ross Stars, 174, 183  
 Ross, A. D., Cooperation of, 268  
 Ross, Frank E., Stellar Research, 165, 175,  
 194, 354  
 Rowntree, Leonard G., Studies of Nutrition,  
 310  
 Roy, Arthur J., ix  
 Roys, Lawrence, Cooperation of, 62, 114, 120,  
 145  
 Roys, Ralph L., Aboriginal American Histori-  
 cal Research, ix, 62, 114, 121, 125,  
 142, 144, 145, 150, 151  
 Ruger, Henry A., Studies in Psychology, x,  
 367  
 Ruling Machines, 192  
 Rumbaugh, L. H., Studies of Isotopes, 258  
 Runyon, Ernest H., Publication by, 404  
 Ruppert, Karl, Studies at Chichen Itza, ix,  
 121  
 Russell, F. H., Publication by, 404  
 Russell, G. Oscar, Studies in Physiology, x,  
 359-363  
 Russell, Henry Norris, Research in Physics,  
 164, 189, 355  
     Publications by, 402  
 Ryerson, Martin A., vi  
 San Jose, Excavations in, 125-128  
 Sanford, Roscoe F., Spectroscopic Studies,  
 vii, 163, 178, 180, 184, 191  
     Publications by, 402, 403  
 Sapsford, H. B., Magnetic Studies, 272  
     Publication by, 407  
 Sarton, George, Study of History of Science,  
 ix, 152-155  
     Lecture by, 385  
     Publications by, 392, 400  
 Satina, S., Studies in *Datura*, viii, 37, 40  
 Sawin, P. B., Mammalian Studies, 285  
 Schairer, J. F., vii  
     Publication by, 107, 399  
 Schmidt, Adolf, Magnetic Studies, 236, 259  
 Schmitt, Waldo L., Diatomaceae, 287  
 Schneider, O., Magnetic Studies, 236, 240  
     Publication by, 407  
 Scholes, F. V., History of Yucatan, ix, 121,  
 125, 150  
 Schonland, B. F. J., Studies in Physics, 343  
 Schooley, J. P., Endocrine Studies, 49, 54, 55  
     Publication by, 397  
 Schulman, Edmund, Chronological Studies,  
 230  
 Schultz, A. H., Studies in Animal Biology,  
 11, 25, 35, 36  
     Publications by, 395  
 Schultz, C. B., Geological Studies, 325  
 Schultz, J. R., Publication by, 319, 392  
 Schultz, Jack, Studies in Heredity, ix, 289,  
 293, 294, 296  
     Publications by, 411  
 Schwyzer, A. G., Studies in Comparative  
 Anatomy, 34  
     Publication by, 395  
 Science, History of, ix, 152  
 Scott, D. H., Cycadeoid Investigations, 334  
 Scott, W. E., Observatory-work, vii, 270  
     Publications by, 407, 408  
 Seares, Frederick H., Astronomical Research,  
 vii, 157, 162, 164, 173, 175, 176, 234  
     Publications by, 403  
 Sears, Paul B., Studies of Early Man, 316, 323  
 Seaton, S. L., Ionospheric Investigations, 250,  
 267, 278  
     Publications by, 405, 407  
 Seigle, L. W., Publication by, 404  
 Seismological Research, vii, 87  
     Advisory Committee in, 35  
     Report of Advisory Committee, 368  
     Laboratory, 35, 37, 321, 370, 378  
 Shark, Studies of, 92  
 Shattuck, G. C., Maya Research, 62, 114, 145  
 Shepard, Anna O., Studies of Pottery, 60, 61,  
 114, 142, 143  
     Publications by, 399  
 Shepard, H. Warren, Studies in Pottery, 144  
 Shepherd, E. S., vii  
 Sherman, H. C., Studies in Animal Biology,  
 x, 56, 7, 71, 75, 314  
     Publications by, 392, 411  
 Sherman, K. L., Atmospheric Studies, vii,  
 243  
 Shook, Edwin, Aboriginal American Histori-  
 cal Research, 115, 119  
 Shreve, Forrest, Desert Investigations, viii,  
 50, 60, 114, 214, 216, 227  
     Publications by, 392, 393, 404, 405  
 Shumacker, H. B., Jr., Studies in Organo-  
 genesis, 11, 12  
     Publications by, 395, 396  
 Sime, Palmer, Studies in Ecology, 287  
 Skogsberg, T., Biological Results, 276  
 Skoog, Eleanor, Publication by, 411  
 Slaucitajs, L., Magnetic Research, 234, 262  
 Smith, A. Ledyard, Studies at Uaxactun, ix,  
 63, 115, 116, 128  
 Smith, Arthur H., Nutrition Studies, 309  
 Smith, G. C., Endocrine Studies, 49, 56  
     Publication by, 397  
 Smith, H. G., Publication by, 392  
 Smith, J. H. C., Studies in Plant Biology, 198  
     Publications by, 405  
 Smith, Robert E., Maya Documentary Re-  
 search, 62, 114, 186, 191  
 Smith, Sinclair, Nebular Investigations, vii,  
 163  
     Publication by, 403  
 Smith, Theobald, vi  
 Snyder, F. F., Studies in Physiology, 25  
     Publications by, 395  
 Sociological Research, 131  
 Solar Research, 166-173, 234, 306  
 Solberg, H., Studies in Meteorology, 306, 307  
 Southwestern Research, 142  
 Spectrophotometry, Stellar, 183  
 Spectroscopy, Stellar, 177

- Spoeher, H. A., *Studies in Plant Biology*, viii, 42, 198, 365, 366  
 Lecture by, 385  
 Publications by, 405  
 Report of Division of Plant Biology, 195
- Sponges, Study of, 86
- Spooner, John C., vi, xii, xiii
- Standley, Paul C., Publication by, 391
- Stanford University, Cooperation of, 37, 216, 230, 298, 365
- Stanton, H. E., *Magnetic Studies*, 249, 270  
 Publications by, 407, 408
- Stebbins, G. Ledyard Jr., *Studies in Genetics*, 302-304
- Stebbins, Joel, *Stellar Research*, x, 17, 158, 165, 175-177, 185, 186  
 Publication by, 403
- Steggerda, Inez D., Publication by, 397
- Steggerda, Morris, *Studies in Anthropology*, viii, 60, 65, 67, 114, 120, 140-142, 145  
 Publications by, 77, 396-398
- Steiner, H., *Organogenesis*, *Studies in*, 12  
 Publication by, 395
- Steiner, W. F., *Mechanical Design*, 252, 277
- Stellar Researches, 174-189, 306
- Sternberg, Elizabeth E., *Solar Research*, 164, 166  
 Publications by, 402, 403
- Stock, Chester, *Studies in Palaeontology*, x, 316, 319, 320  
 Publications by, 319, 320, 392
- Stock, Leo F., ix
- Stone, Raymond C., Publication by, 389
- Storey, William Benson, v, xix, xxii
- Strain, H. H., *Studies in Plant Biology*, viii, 198  
 Publications by, 405
- Stratosphere Balloon Tests, 25, 233, 243-245, 277, 349
- Straus, W. J. Jr., *Animal Biology*, *Studies in*, 31, 32, 35  
 Publications by, 395
- Streeter, George L., *Studies in Animal Biology*, viii, 55, 71, 72  
 Report of Chairman of Division of Animal Biology, 3  
 Report of Director of Department of Embryology, 9  
 Publications by, 393, 395
- Strömberg, Gustaf, *Stellar Research*, vii, 163, 177, 188  
 Publications by, 403
- Strömsvik, Gustav, *Studies in Copan*, ix, 63, 117  
 Publications by, 390, 400
- Strong, Richard P., v, xix
- Sturtevant, A. H., *Studies in Heredity*, 293, 294, 297
- Sun-spot Activity, 167-170
- Supplementary Publications Series, 384, 385, 388, 392
- Sverdrup, H. U., *Oceanographic Work*, x, 275  
 Publications by, 407, 408
- Swallen, Jason R., Publication by, 391
- Sykes, Godfrey, *Studies in Physiography*, ix, 356
- Taft, Charles P., v, xix
- Taft, William H., vi
- Tarr, A. D., *Studies in Cytology*, 16  
 Publication by, 394
- Taylor, M. J., *Publications by*, 397, 398
- Taylor, William R., Publication by, 391
- Tax, S., *Ethnological Research*, 64, 131, 133  
 Publication by, 400
- Tax, Mrs. S., 133
- Taxonomy, *Experimental*, viii, 208-212, 302
- Teller, E., Publication by, 406
- Tennent, D. H., *Studies at Tortugas Laboratory*, 81, 93
- Terrestrial Electricity, 242
- Terrestrial Magnetism, Department of, vii, 8, 22, 51, 60, 114, 161, 166, 341, 342, 386, 405  
 Report of Department, 231
- Thackeray, A. D., *Solar Research*, 165, 171  
 Publications by, 403
- Thayer, William S., vi
- Thompson, J. E., *Studies in British Honduras*, ix, 125
- Thompson, J. W., Publication by, 404, 405
- Thorp, E. M., Publication by, 390
- Three-germ-layer Theory, 9
- Tissue Culture, 6, 7, 17, 18, 20, 83
- Tissues of Cambium, 208
- Tolman, R. C., *Study of Red Shift*, 17, 158, 187  
 Publication by, 401, 403
- Torreson, O. W., *Cosmic-ray Research*, vii, 270, 341, 345  
 Publications by, 408
- Tortugas Laboratory, viii, 50, 68, 3, 8  
 Report of, 81
- Tower, S. S., *Study of Nerves*, 4, 29, 30  
 Publications by, 394, 395
- Transplant Studies, 212
- Tree-ring Studies, 227
- Trigonometric Parallaxes, 174, 182
- Trik, Aubrey S., *Studies in Copan*, 117, 118, 120
- Tucson, *Studies at*, 49, 171, 214, 218, 230, 247, 356
- Tucson Observatory, 272
- Tulane University, Cooperation of, 61, 114, 145
- Tumors, Study of, 20, 45
- Tunell, George, *Publications by*, vii, 109, 110, 399
- Tureson, G., *Studies in Plant Biology*, 211
- Turnage, W. V., *Desert Investigations*, 214, 218, 219  
 Publication by, 405
- Turner, Abby H., *Publications by*, 398
- Turner, R. N., Cooperation of, 346
- Tuve, M. A., *Studies in Magnetism*, vii, 248, 259-261, 278  
 Publications by, 406-408
- Uaxactun, *Studies in*, 62, 68, 115-117, 119, 126, 127
- Ultra-violet Solar Radiation, 171
- Union Carbide and Carbon Corporation, Cooperation of, 346
- United States, Section of History of, ix, 66
- University of Alaska, 246, 250, 277

- University of Arizona, 230, 234  
 University of California, Cooperation of, 37, 226, 317, 320, 364, 365  
 University of Cape Town, 262  
 University of New Mexico, Cooperation of, 146  
 University of Pennsylvania, Cooperation of, 62, 114, 117, 325  
 Urey, Harold C., Studies in Chemistry, x, 299, 301  
 Ursa Major, 185, 188  
 Vacuum Spark, 191  
 van Dijk, G., Magnetic Activity, 240  
 Van Gundy, C. E., Geological Studies, 331, 332  
 Van Maanen, Adriaan, Stellar Measurements, vii, 163, 164, 173-175, 183  
     Publications by, 403  
 Van Niel, C. B., Publication by, 405  
 Varela, Edmund A., x  
 Vaughan, George B., Point Lobos Studies, 364, 365  
 Vaughan, T. W., Publication by, 390  
 Vavilov, N. I., Studies in Plant Biology, 211  
 Vickery, H. B., Studies in Nutrition, x, 308, 410  
     Publications by, 410, 411  
 Victor, J., Leukemic Studies, 45  
     Publication by, 397, 398  
 Villa, A., Ethnological Research, 64, 120, 131-134, 145  
 Virgo Cluster, 15, 157, 186, 188  
 von Brand, Antonia, Studies in Psychology, 367  
 Vuilleumier, Antoinette, Translation of Nutrition Studies, 77  
 Wadsworth, J., Apia Observatory, v, 272  
     Publication by, 408  
 Wadsworth, James W., v, XIX  
 Wager, Willie W., Point Lobos Studies, 364  
 Wagner, G. A., Publication by, 411  
 Wait, G. R., Atmospheric Electricity, vii, 243, 244  
     Publications by, 408  
 Wakeman, Alfred J., Nutrition Studies, 313  
     Publication by, 411  
 Walcott, Charles D., vi, xii, xiii  
 Walcott, Frederic C., v, xix, xxii  
 Walcott, Henry P., vi  
 Wallis, W. F., Land Magnetic Survey, vii, 261  
 Walmsley, R., Study of Whales, 34  
     Publication by, 395  
 Walters, Stanley, Hormone Studies, 53  
 Ward, E. N., Leukemic Studies, 45  
 Ware, Louise, Solar Measurement, 164  
 Washburn, Lloyd E., Publication by, 78, 398  
 Washburn Observatory, 165  
 Watheroo Observatory, 238, 239, 247-252, 262-266, 274, 275, 280  
 Wauchope, R., Investigations at Zacualpa, 128  
 Wedel, Waldo R., Point Lobos Studies, 365  
 Weed, Lewis H., v, xix, xxii  
     Publications by, 395  
     Studies of Cerebrospinal Fluid, 28, 29  
 Welborn, Mary C., Studies of History of Science, ix, 152, 154  
     Publication by, 400  
 Welch, William H., vi  
 Wells, H. W., Magnetic Observations, vii, 249-251, 270  
     Publications by, 405, 408  
 Wen, I. C., Studies in Animal Biology, 35  
 Westall, Roland Gordon, Studies in Nutrition, 311  
     Publication by, 411  
 Western Union Telegraph Company, Cooperation of, 34  
 Whales, Study of, 34  
 Wheeler, John A., Studies in Nuclear Physics, 260  
     Publications by, 408  
 Wheeler, S. M., Geological Research, 320  
 White, Amelia E. and Martha, Cooperation of, 122  
 White, Andrew D., vi, xii, xiii  
 White, Edward D., vi  
 White, Henry, vi  
 White, Priscilla, Cooperation of, 55, 7, 71, 76  
 Whitford, Albert E., Stellar Research, 17, 158, 165, 175-177, 185, 186  
     Publications by, 403  
 Whitin Observatory, 159, 165  
 Wickersham, George W., vi, xix, xxii, 69, 70  
 Wieland, G. R., Cycadeoid Investigations, 333  
 Wiggins, I. L., Desert Investigations, 216, 217  
     Publication by, 405  
 Wigner, E., Research in Physics, 256, 291  
     Publication by, 408  
 Wilbur, Ray Lyman, Point Lobos Studies, 366  
 Wilder, B. B., Studies in Paleobotany, 227  
 Wildt, Rupert, Solar and Planetary Studies, 165  
     Publications by, 402, 403  
 Williams, E. G., Stellar Spectrophotometry, 183  
     Publications by, 403  
 Williams, L. F., Publication by, 396, 398  
 Williamson, E. B., Publication by, 391  
 Willier, B. H., Study of Turtle and Shark, 81, 92  
 Willis, Bailey, Studies in Seismology, x, 68, 379  
     Publication by, 391  
 Willis, Howard C., Stellar Research, 174, 175  
 Wilson, C. B., Publications by, 390, 391  
 Wilson, Elsie A., Nutrition Studies, 77  
 Wilson, Grace P., Stellar Research, 164, 178, 180  
 Wilson, Olin C., Stellar Research, 164, 178, 180-183  
     Publications by, 402, 403  
 Wilson, R. A., Point Lobos Studies, 365  
 Wilson, R. W., Publication by, 319, 392  
 Wilson, Ralph E., viii  
 Wilson, Stanley D., Cooperation with, 71  
 Wintersteiner, M. P., Leukemic Studies, 45  
 Winthrop, M. M., Study in Organogenesis, 11, 12  
 Wintrobe, M. M., Publications by, 396  
 Wisconsin, University of, 260  
 Wislocki, G. B., Studies in Embryology, 10, 72  
     Publication by, 395, 396



- Wood, Harry O., vii  
     Publication by, 379, 409  
 Woodbury, George, Southwestern Research,  
     143  
 Woods Hole Oceanographic Station, Coopera-  
     tion of, 34  
 Woodward, Robert Simpson, v, vi, 380  
 Wright, Carroll D., vi, xii, xiii  
 Wright, F. E., Lunar and Planetary Investi-  
     gations, vii, 20, 165, 173, 234, 343,  
     355, 381  
 Wright, Hamilton, Study of the Moon, 165,  
     173  
 Yellowstone National Park, 68
- Yerkes Observatory, 165, 170, 175  
 Yonge, C. M., Publications by, 390  
 Yost, F. L., Studies in Nuclear Physics, 260  
     Publications by, 408  
 Yucatan, Studies in, 60-62, 68, 77, 114-146,  
     152, 279  
 Zacualpa, Investigations at, 128-130  
 Zeeman Patterns, 162, 189  
 Zeiss Condenser, 86  
 Zies, E. G., Pottery Studies, vii, 143, 144  
     Publication by, 393  
 Zmachinsky, A., Studies in Metabolism, 75  
 Zósé Observatory, 262  
 Zwicky, F., Publications by, 411





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